MACHINE TOOL RECONDITIONING

and

Applications of Hand Scraping

by

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PREFACE

The purpose of this book is to supply a deficiency of long standing in the metal trades for a comprehensive exposition of the hand scraping art and its principal application, the reconditioning of machine tools. The author has attempted to set down in simple language, not only the basic principles and practices, but also the more advanced techniques utilized by skilled, experienced scrapers.

The arrangement of this book has a two fold purpose. First, to acquaint the novice with the basic scraping procedures and to teach the principles involved. Second, to apply this knowledge to the specific problems of machine tool reconditioning.

In describing the methods employed in treating the various machine tools, a progressive, step by step procedure is followed. Starting with an outline of the components, each part is sub-divided into its constituent bearing surfaces. The OBJECTIVES required of each surface are established, and accompanied by a more or less detailed explanation of the recommended treatment. In other words, each part of the entire operation is given and presented in the logical order. It should answer the questions "Where do I start?" and "What next?" Where sound alternative procedures are possible, they are mentioned. This has been done, not to make the work encylopedic in content, but to suggest the use of other apparatus equally appropriate.

Each major operation, and many minor ones, are graphically illustrated by perspective and mechanical drawings. These show the physical set-ups and utilize the very minimum of standard equipment. Many of the diagrams show the permissible tolerances in connection with alignments.

The subject matter has been arranged, as far as possible, to make it useful as a hand book for foremen and other supervisory personnel. Both the section headings and index should make possible the rapid finding of essential information. For experienced operators, the illustrations alone should solve many problems with little reference to the text.

Most of this information cannot be found in standard engineering handbooks, machinist's manuals, or even in books dealing with the mechanical trades generally, but it is nonetheless indispensable to anyone charged with the responsibility for maintaining, at highest efficiency, the production machinery of mill, factory, or shop.

The status of hand scraping in modern industry is an important one. It is an integral operation of machine tool building and repair, which is the key industry of America's mass production system of manufacture. Moreover, it is an essential process in the production of master gages for factories.

Although there have been many technological advances in machine design, new processes developed in metallurgy, innovations in metal hardening and in grinding practice, this progress has not diminished the need for hand scraping. Machines have not yet replaced the skilled scraping operator, nor are they likely to. In the manufacture of industry's master tools, such a development is even less probable.

Naturally, scraping ability cannot be cultivated in a day. To become a skilled scraping operator requires not only much practice and varied experience, manual dexterity and physical strength, but also great patience and an equable temperament. Thus it is obvious that not all are fitted for the task. However, for those qualified, the period of learning may be materially shortened by a study of this book and correct application of its principles. While an occasional short cut may be taken on some of the procedures discussed, these are for the skilled practitioner and not for the novice. Experimentation, legitimate as it is, ought not to be too freely exercised when reconditioning costly machines. If the novice will conform to the procedures herein described, there will be reasonable efficiency for the effort expended.

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Chapter 1

THE ART OF SCRAPING

In this chapter we will introduce hand scraping to the beginner in the machinist's trade. This subject scarcely needs any introduction to experienced machinists who know well its laborious processes. The tedium and the difficulty of the work have been, and still are, standing invitations to "Yankee ingenuity" to make improvements in the metal working trades. Undoubtedly, great strides have been made, but despite the rapid advance of technology in the mechanical fields it still is not possible to produce with either a reciprocating or rotary tool, except under special conditions, the true, flat, close-grained surfaces that are essential for a first class bearing. This is the reason that practice in hand scraping is desirable in the training of apprentices. It is also the reason why proficiency in this art ranks high among the machinist's acquired skills.

Sec. 1.1
Definition of Scraping

Scraping is that hand process which produces a flat, close grained surface on work which is finish machined. It is the final delicate removal, flake by flake, with a hand tool, of the minute irregularities which, though scarcely perceptible to the eye, stand up like saw teeth on the metal surface of the work. The removal of this roughness, without destructive effect to the remainder of the surface, comprises the art of scraping.

Another way to express the same thought is to define scraping as an operation to eliminate the high spots on machined surfaces thereby producing bearing spots that are in one plane.

Sec. 1.2
Plane Surface in Theory and Practice

To prevent future misunderstanding it is important to realize exactly what the term plane surface, or flat surface signifies. A plane surface is defined as a surface such that if any two points on the surface be joined by a straight line, every point on the line will be in contact with the surface. In other words, it is a surface without rotundity, curvature, depression or other variation or inequality. Practically speaking, it cannot be achieved by any known process, be it hand scraping, surface grinding, super-finishing, lapping, etc.

A flat surface, therefore, is merely relative. It is usually considered to be a surface which will bear on a theoretical plane at a sufficient number of places to satisfy accepted standards.

In each trade, or art, the term "flat" will be accorded a different meaning. The carpenter accepts the smoothly finished wooden level, or steel square, accurate within thousandths of an inch, as sufficiently flat to be used as a reference to gage his work.

This basis is not acceptable to the machinist because it is too crude. His measurements range into tenths of thousandths of an inch. The SURFACE PLATE, STRAIGHT EDGE, and PRECISION LEVEL are his representative standards of flatness.

This is not the ultimate by any means. Even higher requirements are demanded by the gage maker, whose gages must be accurate to millionths of an inch. Fortunately, such precision is not required in the hand scraping process.

It thus can be seen that in referring to flatness, we are not alluding to some theoretical ideal but rather have in mind the practical possibilities of producing a flat metal surface by hand scraping.

Sec. 1.3
Hand Scraping Sliding Bearings

The principal use of the hand scraping process is to improve the bearing quality

of slides and ways and at the same time to correct the alignment of machine members. During manufacture, hand scraping is required in greater or lesser degree on nearly all machine tools. It is also extensively employed in the reconditioning of worn machines.

As an alternative procedure for hand scraping, precision surface grinding may be utilized, but ordinarily this requires special purpose machines. Furthermore, this process would be economical only for mass production manufacturing. The cost of reconditioning a single machine, or small lots of miscellaneous types and sizes, would be prohibitive. Consequently, in this field, hand scraping is the undisputed choice.

Sec. 1.4
Hand Scraping a Fixed Bearing

In addition to sliding bearings another classification of machine parts is often scraped, namely members that bolt together. This is required when it is necessary to preserve a definite alignment or to prevent warping one or both members when clamping two uneven surfaces together.

Another use for hand scraping is in fitting two members to form a seal against the leakage of oil or other fluid.

When scraping members to a close fit for any of the purposes above stated, smoothness and flatness of the surfaces should be the main considerations.

Sec. 1.5
Comparing Methods of Producing Flat Surfaces

As stated previously, there are several methods of producing flat surfaces besides hand scraping. But these alternatives, machining, surface grinding, lapping, are not universally applicable. For example, planing machines can produce surfaces that are practically flat and true but to do so they must be in good condition and perfect alignment. It is standard practice among shops which use planers in the building of precision machinery to reserve one or more machines for finish machining while others are used for roughing. Incidentally, after finish planing a work piece of, say, cast iron material, a sort of fuzz is left on the machined surface by the planer tool. It is customary to scrape it off lightly, not to make the surface flatter, but merely to improve its looks. Sometimes a fuzzed surface is rubbed down with abrasive blocks or frosted with a scraping tool. These operations should not be mistaken as processes to produce a flat surface. They are simply expedients performed for appearance' sake only.

As for surface grinding, producing flat surfaces by this method is restricted by the size of the machine. A surface grinder, because of limitations of size, produces flat surfaces of comparatively small proportions measurable in square inches. When flat areas of many square feet are required, hand scraping is often the machinist's only recourse. It is seldom that he has at his disposal a machine capable of grinding surfaces of sizeable dimensions to an accuracy equivalent to hand scraping. This is the general rule because the average machine shop is equipped with only the smaller size of surface grinder. We do not mean to imply that large, specially built, grinding and lapping machines are not capable of producing extremely flat surfaces of ample extent.

The process of lapping can be dismissed by saying that it is very laborious and resorted to only when the metal surface is too resistant to the penetration of the edge of a cutting tool.

Thus we can see that due to the limitations of machine methods for producing flat surfaces, hand scraping is frequently the logical alternative for the average machine shop to apply.

Sec. 1.6
Definition of High Spots

A high spot in scraping parlance means an elevated area, such as a point or ridge that is higher than the average height of the work surface. On a smoothly scraped surface, a high spot is imperceptible to the eye because it is only thousandths, or tenths of thousandths of an inch above the average level of the surface. However, after spreading a film of marking compound on the true plane of a tool or template and applying the gage to the work surface, a portion of

the thin film is transferred to the individual high spot i.e., rubbed off. The high spot so treated is then plainly visible. It is this process that makes hand scraping feasible.

At the initial spotting of a worn surface, the markings disclose that the high spots are comparatively large in extent as well as relatively high. This is revealed by the expanse of the marked areas and by their coloration. After the scraping operation begins, the end of each cycle sees the concentrations of high spots broken up into successively smaller sizes and simultaneously reduced in height. By degrees, they are worked over with the scraping tool, until they are of the same height and uniformly distributed. At this point the objectionable high spots merge into what is known as bearing spots. Thus bearing spots are simply the high spots scraped until they are of one even height, or plane, and uniformly distributed.

The scraping process is one wherein the high spots are gradually changed in form from relatively broad patches of uneven height, as the process begins, to bearing points which have many shapes, varying from small spiked cones to razor-edged ridges, all lying in one plane, by the time the surface is finished. The bearing spots do not remain in this condition for long though. As soon as the machine is placed in use, the sliding pressure of the mateing member begins to wear down these sharp points. Gradually they broaden and merge with others to form an expanse that is plainly discernible if a film of marking compound is applied.

The heavier the bearing pressure imposed, the more rapid the transformation of these points and the broader and more conspicuous they become. Long periods of normal operation, causing wear also produces this effect.

In other words, the surface is more accurate immediately after it is scraped. Thereafter, abrasion begins and deterioration sets in. By degrees the size of the individual bearing spot increases. Gradually it merges with adjacent spots. Wear continues until the bearing quality of the surface is impaired by the evolution of new high spots, whereupon reconditioning is again imperative.

Sec. 1.7
Generating Bearing Spots

Bearing spots, which comprise the contact surface of ways (or slides), are formed in the process of scraping high spots to one overall plane. Bearing spots so produced do not have any uniform shape. Some will be oval or rectangular, others will be irregular, but this variation does not affect their function. Their size, that is the area of their contact surface, will be determined largely by the length, width, and depth of the strokes that form them.

A stroke producing a short, narrow, shallow scraping cut is requisite to generate bearing spots. Varying these characteristics in any respect changes proportionately the number of bearing spots per square inch of surface.

Sec. 1.8
Relationship of Scraper Marks to Bearing Spots

The area of the average scraping mark determines the number of bearing spots per square inch. The greater the area, the fewer the number and vice versa. Bearing spots invariably form along the junction between two individual scraping marks and not in the hollow shaped by the scraping stroke. The reason that a concave incision is made is that the cutting edge of the flat scraper blade is curved, as shown in Fig. 5.2a. Obviously, therefore, the rim and not the middle of the depression will constitute the bearing spots. An examination of the surface of a work piece following a scraping cycle will reveal this. For example, if the length of the scraping strokes applied to a surface are shortened, the area of chip removal is also reduced. The effect is to increase the number of bearing spots per square inch. On the other hand, longer strokes each gouging a greater area results in fewer bearing spots per square inch of surface.

The scraper proportions his strokes to the type of bearing surfaces needed, although speaking generally, the cuts made at the start of a job are both longer and deeper than those executed at the finish.

Sec. 1.9
Quality of Surface Bearing

How many bearing spots should a scrape-finished surface have? This question can only be answered by considering the type of bearing desired. Surfaces having stationary, or fixed, contact with each other will be found satisfactory with 1-5 bearing spots per square inch. When ways and slides, which perform average service are involved, about 5-10 bearing spots per square inch are specified. For sliding bearing surfaces designed for precision work, such as the general run of machine tools, 10-20 bearing spots per square inch will be necessary. Precision gages, SURFACE PLATES, etc., require 30-35 bearing spots per square inch. In short, the requirements of each individual surface must be judged in the light of the experience of the scraper, with due consideration given to the type of service it is to perform.

As a rule on the average job, the number of bearing spots per square inch of surface are not physically counted by the scraper. This would be unnecessarily tedious. Instead the quality of the surface bearing is judged by a well trained eye. (Naturally, this ability is not cultivated in a day.) Thus on the final spotting cycle an estimate is made of the bearing quality from the appearance of the colored markings. (Incidentally, such factors as the thickness of marking medium used, and the degree of spotting pressure can impair the correctness of this estimate.) This conclusion must be correlated with the anticipated conditions of service. A decision is then made as to whether or not the bearing surface can be considered scrape-finished. This is often expressed by a term "percent of bearing."

Sec. 1.10
Percent of Bearing

Not infrequently instructions are given to a mechanic to scrape a surface to, say, a 75% bearing. The diversity of opinion as to the meaning of the expression "Percent of Bearing" is one of the greatest sources of confusion in the machine shop. It is easy to see how it could lead to serious mistakes in the interpretation of orders. This is all the more understandable when consideration is given to the several factors that necessarily enter into the term.

Percent of bearing, broadly speaking, refers to the proportion of a surface that is covered by a marking medium, such as bluing, transferred to it by a SURFACE PLATE, STRAIGHT EDGE or other spotting gage. Obviously, the quantity of bluing (or other media) spread on the tool determines in large measure the amount transferred to the work surface. Similarly, the oil content of the marking compound affects results. The expertness in handling the spotting tool also exerts an influence because clumsy application induces added pressure. Likewise excessive rubbing causes more bluing to be transferred. Then there is the question of lighting and vision. Under conditions of bright daylight the bluing marks are more visible than under poor artificial lighting. The weight of the spotting tool in relation to the area of the work surface spotted i.e., pounds per square inch, should also be considered. As a final factor, there is the condition of the work surface itself. When finely scraped it is somewhat more retentive of bluing than when it is less smooth.

It can be seen from this that any precise definition of percent of bearing surface is utterly futile because of the variety of conditions that prevail and the individual interpretation of the transferred markings. Each operator, consequently, would have a different opinion as to the percent of bearing of any given surface.

On a few things, however, all do agree, namely:

1. The amount of marking medium transferred to the work surface should be the very minimum so that the operator must look closely under a good light, to observe the markings.
2. The tool must be handled expertly, with a minimum amount of rubbing motion.

If this explanation leaves the reader with a sense of frustration, it is only natural. In the final analysis the percent of bearing is subject to individual judgment and is not calculable by any simple formula.

Sec. 1.11
The Scraping Cycle

In the language of the trade, a number of diverse operations are lumped together under the category of scraping, although to be technically correct the term should be restricted to the process of shaving small particles from metal surfaces. However, no confusion results from this looseness.

Speaking generally, scraping comprises a series of procedures leading toward the production of a flat metal surface. To produce an accurate flat bearing plane, the high spots, which may be two or three thousandths of an inch higher than the average height of the work surface, must be removed. To detect them requires the application of marking compound by either the spotting or reverse spotting methods.

One object of scraping is to reduce these irregular high spots to a uniform height or plane at which time they can be classified as bearing spots. Other fundamentals of scraping require that the bearing spots be uniformly distributed and adequate in number for the class of work intended for the machine.

To accomplish these results, scraping is conducted in an orderly sequence of operations, dubbed a cycle. This routine is repeated as often as necessary until the OBJECTIVES are accomplished. The logical order is as follows:

1. Removal of burrs.
2. Spreading of marking medium.
3. Application of spotting tool.
4. Analysis of the markings.
5. Scraping of indicated high spots.
6. Cleaning of surface.
7. Removal of burrs etc., as the cycle is repeated.

Each of these steps is taken up separately in this book, though not necessarily in the order enumerated.

When treating a worn surface, the first cycle will usually show only a few high spots and these will be more or less isolated and apt to be large. They are scraped off, burrs are removed etc. The next cycle will reveal an increase in the number of high spots and a diminution of their size. As the scraping operations continue, the number of high spots multiplies and their area is reduced. Ultimately, these high spots are well distributed over the scraped surface and gradually merge into what is called bearing spots. This result is achieved as much by a calculating judgment of where and how much to scrape, as by the actual mechanical removal of the metal particles.

It should be pointed out that the attainment of flatness and satisfactory bearing quality in a surface is fundamental to every scraping job, but frequently more than that is needed. An additional consideration would often be the need to align the surface being scraped with another plane. In actual practice, dealing with such cases calls for alignment tests to be performed periodically at the conclusion of operation #7 (removal of burrs).

Chapter 2

PERSONAL REQUIREMENTS

Before discussing the tools and methods of the scraping art, it would be advisable to say a few words about the men who use them.

Sec. 2.1
Qualifications

Hand scraping, as anyone who has tried it knows, is a tedious job demanding rigorous concentration. While it is possible for any person to manipulate a hand scraper, expert handling requires know-how, practice, and the possession of a natural aptitude.

Training in handling the various tools and gages, in applying marking medium, and in conducting scores of complex tests, is requisite to success as a scraping operator. If, in addition to this experience, the individual possesses certain physical and mental characteristics for the work, he is more likely to be successful at it.

Since the work is very fatiguing, the mechanic should have a liking for muscular activity as well as the stamina to keep going. Good vision is essential to detect individual high spots, often minute in size.

Proficient scrapers have a high degree of manual dexterity and a delicate touch. The need for this is understandable when it is realized that in the final pin pointing of gages, precision tools etc., the metal may be flaked off in .0001" thicknesses, much finer than a human hair.

Unsteadiness of hand rules out many otherwise acceptable mechanics. Hard drinkers eliminate themselves. Age is seldom a limitative factor. The older man possesses patience and experience not usually found in younger men.

Personality has a lot to do with making a scraping specialist. The work is monotonous, yet demands intensive effort and unflagging concentration. There must be meticulous attention to details. Dogged perseverance, in the face of unexpected set-backs, is as imperative as the ability to hold one's temper. Anyone disposed to throw his tools around under slight provocation is not likely to be a success at this work. The individual with calm, phlegmatic temperament is superior as a scraper to his peppery counterpart.

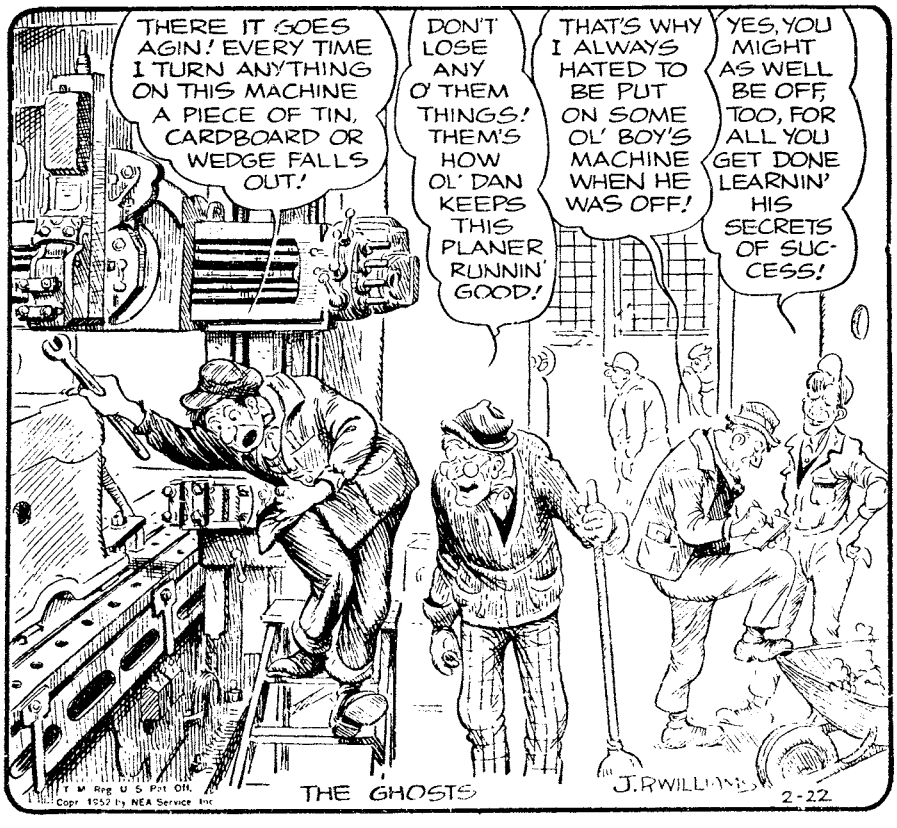
Those who crave company, who keep up a constant line of chatter, and move around the shop to visit friends, are definitely out of place as scraping operators.

Self reliance and confidence in one's ability are required in scraping work. This is only natural considering that responsibility must be assumed for machines worth many thousands of dollars.

Another desirable characteristic is independent judgment. There is more than a little reason to believe that it is essential to success in this trade, at least in some degree. For instance, although a certain mechanical routine must be followed without deviation while scraping, there is, nonetheless, ample opportunity for the scraper to display discrimination. There is a wide field of choice as to scraping strokes, selections of marking compound, kinds of tools etc. Procedures, too, can be varied because scraping is not so inelastic a process as machining metal. Then there is the matter of the choice of methods for improving the attractiveness of the work surface, which is an important requirement in commercial scraping work. This means much more than discerning and camouflaging scratches and blemishes on work surfaces. It connotes an appreciation of, and the ability to produce, decorative effects such as frostings, whenever needed.

There is one final quality, essential to success in any trade but especially important in scraping. This is pride in craftsmanship. In scraping operations it is often possible to skimp a job because fellow workmen of average mechanical skill are unable to recognize whether the work is properly done or not. Only experts are qualified to conduct

accuracy tests. Thus so long as the scraping improves the work surface slightly, even though temporarily, a negligent operator "gets by" for a time. Eventually, however, his lack of integrity will be discovered. This type of man is particularly unsuited for a scraping specialist.


OUT OUR WAY
BY J. R. WILLIAMS
THERE IT GOES AGIN! EVERY TIME I TURN ANYTHING ON THIS MACHINE A PIECE OF TIN, CARDBOARD OR WEDGE FALLS OUT!
DON'T LOSE ANY O' THEM THINGS! THEM'S HOW OL' DAN KEEPS THIS PLANER RUNNIN' GOOD!
THAT'S WHY I ALWAYS HATED TO BE PUT ON SOME OL' BOY'S MACHINE WHEN HE WAS OFF!
YES, YOU MIGHT AS WELL BE OFF, TOO, FOR ALL YOU GET DONE LEARNIN' HIS SECRETS OF SUCCESS!
THE GHOSTS
J.R.WILLIAMS
2-22
T M Reg U S Pat Off.
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Chapter 3

CHARACTERISTICS OF METAL

To enhance their usefulness to industry a variety of metals are hand scraped. These include steel, cast iron, copper, lead, aluminum, brass, and babbitt metal, in various grades and alloys.

Cast iron, or grey iron, as it is better known in the trade, is perhaps the most extensively used material for machine parts, jigs and fixtures. A high percentage of machine members that are scraped is made of this material. Semi-steel is also widely utilized.

Doubtless much more that is both learned and interesting could be said about metals, though such a subject is hardly appropriate for a book of this nature. However, scrapers will experience in the course of their work, several phenomena that deserve added comment.

Sec. 3.1
Expansion of Metal

To the layman, metal is a hard material which holds it shape to a remarkable degree even under great stress. But to men who work with it, metal is something less than rigid. For example, the machinist is in a very good position to judge the effect of heat on metals. He realizes that, if dimensions must be held, no finishing cut can be taken on a work piece while it is hot. It is a simple experiment to prove with a "tenth" micrometer that metal expands from the effect of heat.

With high accuracy tools at his disposal, the scraper is well prepared to detect the twist or warp induced in a surface by heat. Spotting with a SURFACE PLATE or STRAIGHT EDGE, it is an easy matter to determine the effect of the summer sun shining on a corner of a machine member. Even a few minutes of exposure will so distort the surface that further spotting must be suspended until the work piece is removed from the sunlight and recovers an even temperature. Only then is it feasible to resume operations.

If the effect of heat on metal is fully appreciated, the scraping operator will never be found guilty of placing precision spotting and testing tools where sunlight can reach them. They were scraped-in at room temperature (68°) and their accuracy decreases as they vary above or below that figure. Thus if new spotting tools should be received from the factory in the dead of winter, they must be allowed to warm to room temperature before being used. For tne same reason, precision tools must never be stored in proximity to furnaces, radiators, steam pipes etc.

Sec. 3.2
Bending of Metal

Another indication that metal is not as rigid as popular opinion has it is evident in its tendency to warp when unbalanced. All machines will warp unless they are supported solidly and occupy the same level position that they were in when scrape-finished. The horizontal plane being the universally accepted datum line, machines are scrape-finished in a level position. If moved, they must be releveled after relocation in order that the flat bearing surfaces will straighten out and re-assume their original alignment. When re-erected, weight distribution of the main casting must be the same as it was when the machine was first scraped-in at the factory.

Individual machine members also need to be adequately supported. For example, a grinding or milling machine table, if supported on blocks placed at each end during scraping operations, will immediately begin to sink in the middle. The curvature is apparent in a matter of minutes if a spotting tool is applied. The trend can be halted by balancing the table on one block, only, set under the middle. If this is done, the ends will commence to sag, reversing the process.

Frequently, in dealing with relatively long, thin castings which are visibly warped, it is possible to straighten them to a considerable degree by such means, thereby saving many hours of scraping.

The bending of test bars is also a serious problem when conducting alignment tests. Although the deflection of a bar held at one end in the spindle is only in thousandths of an inch, it still amounts to a considerable proportion of the permissible tolerance. This subject of sag in test bars is amplified in Sec. 15.7.

Sec. 3.3
Burrs

Another phenomenon that is common to the cutting of metal is burrs. Burrs are formed by all machining operations and must be removed, or blunted, before applying highly finished spotting tools to the relatively rough surface.

Scraping Burrs

Scraping burrs are ridges or jagged points raised on a metal surface by the cutting edge of a hand scraper blade. They are so destructive to the fine surfaces of testing tools that they must be removed regularly before each application of the gage to the work piece.

Sec. 3.4
Formation of Scraping Burrs

Every time a flake of metal is scraped away, a burr is raised along the sides of the furrow. The burr is higher and therefore more noticeable at the point the blade emerges, or stops, at the end of the stroke. It may be either visibly apparent or so small as to be almost imperceptible to both sight and touch. There is no way to prevent burrs from forming on the work surface with each stroke of the blade. A deep cut, removing a large flake of metal, will produce a correspondingly large burr; a shallow cut generates a small burr. Thus all finish scraping strokes should be as light as possible, consistent with the quality of bearing required.

The length of the stroke is also a factor determining the size of the burr. A long stroke is usually also a deep one with the resultant burr appearing as mentioned above.

The method of using the tool is a major influence affecting the size of the burr. A scraping stroke powered by the arms is likely to leave a more prominent burr than a stroke powered by the body. A brief outline of each technique as it affects burr formation is given below, but for a detailed description of the manner of executing the arm and body strokes, the reader is referred to Sec. 6.1 and Sec. 6.2 respectively.

When the arm stroke is adopted, power is exerted to force the blade in a straight line, sloping through the high spot being removed. At the end of the stroke, the blade halts abruptly, still in contact with the metal and below the plane of the work surface. In many cases this thrust is followed immediately by one or more additional strokes, each cutting deeper and all stopping at or about the same point. The burr raised in front of the cutting edge by this technique remains attached to the work surface. It is obvious that the size of burr formed by the arm stroke method is large.

On the other hand, with a stroke powered by the body, the cutting edge follows an elliptical path instead of a straight line. Thus the cutting edge of the blade bites into the high spot and passes upward. The movement ends with the edge of the tool above the work surface, never on it or below it. With the body power stroke, this is entirely possible because in most cases sufficient momentum is generated to slice cleanly through the high spot. Enough additional momentum is available to do this and continue with a follow through (as in golf) that ends with the tool edge somewhat above the work surface.

The body powered stroke cuts in an elliptical path. It starts slowly downward, increasing in depth more rapidly than the forward movement. The greatest depth is reached directly below the center of the spot being scraped away. As the forward movement of the stroke continues, the blade is brought up and the stroke ends with the cutting edge above the work surface.

An analysis of the two methods of applying the cutting stroke shows clearly that on the basis of chip size, scraping with body power develops a smaller burr than an arm powered stroke. Comparison

further reveals that with either method, short, light strokes produce burrs that are almost imperceptible.

Sec. 3.5
Types of Metals Affecting Burrs

Burrs raised on steel work surfaces are larger and harder than the burrs affecting cast iron and other metals. Regardless of the kind of metal being scraped, however, burrs must be removed from the work surface before the STRAIGHT EDGE or SURFACE PLATE is placed on it. Otherwise, rapid destruction of the tool's face will result, due to roughening and scratching.

Sec. 3.6
Removal of Scraping Burrs

To remove burrs formed in the scraping process, a burr file is preferable to a bench stone. The latter will produce noticeable scratches in the work surface, and the coarser the grit, the deeper the scratches. On the softer metals, such as lead, aluminum, and brass, the bench stone will soon be loaded and become useless. A well worn burr file (See Sec. 4.1) is more satisfactory as it will neither scratch nor clog.

When removing scraping burrs the most satisfactory technique is to rub either of the abovementioned tools in a to and fro, not a circular motion. This should be continued until the hand can no longer detect the presence of burrs. After cleaning away the debris it is again safe to apply the spotting tool.

Sometimes a hardened flat steel block is used. This block doesn't actually remove burrs; it merely knocks down, or blunts, their sharp points. It is not as effective as the apparatus discussed above, except on non-ferrous surfaces.

Sec. 3.7
Dent Burrs

In addition to scraping burrs, such as we have described, there is another type of blemish known in the trade as a dent burr. A dent burr is caused when a tool or heavy object is dropped on a bearing surface. The blow forms a small depression, surrounded by a raised area. This protuberance cannot be economically removed by the tools suitable for reducing scraping burrs. It must be filed or scraped away.

Sec. 3.8
Chilled Surfaces

Scrapers sometimes encounter bearing surfaces that are notable for their exceeding hardness. This characteristic is produced when the member is cast. A portion of the molten metal flows against a cold metallic insert in a sand mold and is instantly chilled. The surface so formed is extremely hard and will resist ordinary abrasion much better than the softer mateing surfaces, such as cast iron or semi-steel, which may be fitted to it. Most of the deterioration caused by sliding friction will, therefore, take place on the softer material.

If realignment of a chilled surface is ever required, hand scraping is out of the question because the skin is practically impenetrable to the blade; only surface grinding can cope with it. Consequently, it will often be more convenient to align such a machine member by hand scraping its other bearing surfaces which have not been chilled.

Generally speaking, iron chills are used on surfaces subject to intensive wear. For instance, manufacturers of milling machines sometimes condition the top of the table, the slides of the knee, and other surfaces in this fashion.

In passing, it might be noted that flame hardened surfaces belong in the category of hardened surfaces, although they are produced by different technological methods. The bed ways of some types of lathes, for example, are manufactured by this process.

Chapter 4

TOOLS

The essential equipment used in scraping is divided generally into three classifications. There is no hard and fast division between them, but for clarity they may be grouped as follows:

1. Personal tools and auxiliary shop equipment, including:

   Hand scraper; marking mediums, such as Prussian Blue, blue spotting paste, Red Lead, alcohol etc.; bench oil stone; files; groove cutters; lead hammer; hardened steel blocks; turn tables; power scrapers; and hand sanding disc grinders.

2. Spotting Tools, which include:

   The SURFACE PLATE, standard STRAIGHT EDGE, ANGLE STRAIGHT EDGE and hand TEMPLATES.

3. Alignment tools, such as:

   Steel Try Square, Box Square, scraped triangle, thickness gages, ground and scraped PARALLELS, Precision angle plates, V-blocks, ground cylinders, Test Bars, PRECISION LEVEL, Surface Gage and indicating jigs, DIAL TEST INDICATOR, telescopic gage and micrometer.

Independent treatment and greater emphasis will be given to some of these items when such a course is warranted, either by their importance, or by the complexity of handling the apparatus. On the other hand, it will make for convenience if a number of items of lesser importance but of general interest are combined together, as is done in this chapter.

Sec. 4.1
The Burr File

Files of many shapes and sizes are frequently used by the scraper for incidental purposes, but only one of special interest will be discussed. Included in every scraping operator's tool box should be a "burr" file. This is simply a flat, double cut, smooth file, 8" to 10" in length, having no handle. A flat safe edge is ground on one edge and a bevel of approximately 30^{o} is ground on the other edge. The safe edge facilitates the removal of burrs close to a square corner while the beveled edge allows access all the way to the bottom of a dovetail.

The flat sides of the file are used to knock down the burrs. For this reason an old, well worn file is preferred to one with sharp teeth. Our purpose is not to abrade the metal work surface, as the term "filing" implies, but to eliminate roughnesses. We accomplish this by applying pressure to the file and rubbing it over the burrs, removing them but without scratching the nicely scraped surface.

If circumstances require a new file to be used, the teeth should first be dulled on a bench stone.

Sec. 4.2
Groove Cutter

For cutting or enlarging grooves adjacent to corners, or in dovetails, one of the handiest tools is a groove cutter. This little gadget is often more convenient to use than a knife edge file and is efficient under all conditions.

The construction of such a device is simple. It is made by riveting together three 12" power hacksaw blades in a triangular shape, as shown in Fig. 4.1. Before riveting the blades together, the rounded ends are first ground off straight. By eliminating the double thickness in this way, it is possible to use the blade in narrower dovetails. To protect the hands from the sharp saw blade teeth, tape is wrapped around two of the blades to form handles. Owing to the rigidity of the truss design it is possible to place the hand

grips well away from the working blade. This keeps the operator's hands safely removed from possible contact with sharp edges or corners of the work piece.

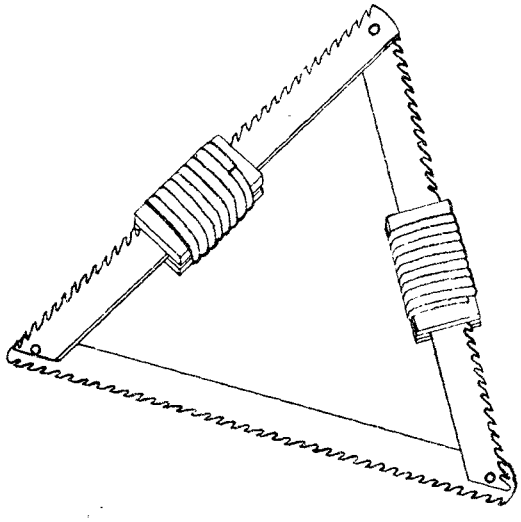


Fig. 4.1 Efficient groove cutter made from hack-saw blades riveted together.

The groove cutter is manipulated like any two handled saw. When a heavy pressure is exerted on the tool, grooves form quickly.

The width of the groove that will be cut with this tool is not excessive. It is approximately equal to the thickness of the teeth of the power hack saw blade. To make a narrower groove, grind off the "set" in the saw teeth.

Sec. 4.3
Vernier Bevel Protractor

The vernier bevel protractor is employed to measure angles on short lengths of stock. It is widely and successfully used in the tool room for such purposes. However, when reconditioning machine tools, which involves scraping one bearing surface to a predetermined and constant angle with another surface, it is not nearly so effective.

The bevel protractor must be sighted at eye level towards a strong light if an accurate result is to be obtained. The accuracy of the test decreases the further the eye is removed from the protractor.

Thus with machine members whose bearing surfaces are of considerable length, the check must be conducted at progressively increasing distances from the operator's eye. If viewed obliquely from a closer position, results are even less satisfactory because it is then more difficult to observe how the light is showing between the blade and the work surface. Furthermore, since it makes only a line contact, determining progress on a scraping job with this instrument will entail repetitious and time consuming checking. Where only a narrow surface is available for testing, results with this tool are particularly unreliable.

When accurate alignments must be made, the vernier bevel protractor is a poor substitute for a spotting template even if the latter must be made special for the individual job. Of course, in making the template, which usually is short in length, the vernier protractor can be efficiently employed.

Sec. 4.4
Surface Gage

In general machine work the Surface Gage serves a number of useful purposes, chiefly scribing lines at varying heights or distances from a base. For scraping and alignment operations, the Surface Gage is most frequently used as a base or stand for a DIAL INDICATOR fastened to the arm. It is shown in numerous places throughout this book.

Sec. 4.5
The Hand Sanding Disc Grinder

For removing quickly a considerable thickness of metal, the hand disc grinder is a very efficient device. It a piece of work is awkward to handle, requiring much time to set up in a milling machine or planer, the job can usually be done far more rapidly with a disc grinder.

In choosing a model for a tool room, remember that compactness and light weight must go hand-in-hand with maximum power and effectiveness.

When operating with this tool, proceed as follows:

As a first step, an ample quantity of marking compound is spread on the

spotting tool because the work surface will become quite rough as the operation proceeds. This thick coating of compound will protect the tool against scoring and, furthermore, provide readily distinguishable markings to aid in identifying the high areas.

After the compound is transferred, the disc grinder is applied with short, brief strokes to the high areas of the work piece indicated by distinctive markings. The proper technique is to merely poke at the markings, meanwhile holding the flat side of the disc at a slight angle to the work surface so that the face of the disc is turned slightly at the rim. Since the sanding disc is flexible, it will bend readily.

Grinding should never be continued overlong in one place lest there be formed a destructive hollow that requires hours of hand scraping to rectify. It is better by far, to grind too little, than to risk going below the finishing level of the work.

Extreme care is needed when working near an edge on a work piece to avoid turning it, i.e. grinding an irregular curve or bevel. In the hands of an unsupervised novice, the disc grinder is apt to be a dangerous implement, but with experience and reasonable care, it saves much time and back breaking labor.

To prevent possible injury to the eyes from flying grit, safety goggles should be worn.

Sec. 4.6
Turn Tables

Modern scraping departments are equipped with one or more turn tables. Their use enables the operator to place his work in the most convenient position for spotting and scrapping and to obtain the advantage of the best light. When the work piece can be turned about easily, speed and efficiency are increased.

One versatile design of turn table is shown in Fig. 4.2. This construction, which is patterned after welding positioners, has a number of features that are especially helpful to the scraper. It has a two piece column (1) and (2) comprising essentially an elevating screw, resting on a heavy plate (3), bolted to the floor. This construction makes possible a 369° rotation and 12" to 18" of elevation. The table top consists of two flat surfaces (4) and (5), welded to each other at a right angle. T-slots are milled in the top in both directions. This design permits either a work piece or planking to be bolted to the table top. By driving nails into the planks, small work pieces can be held in position conveniently.

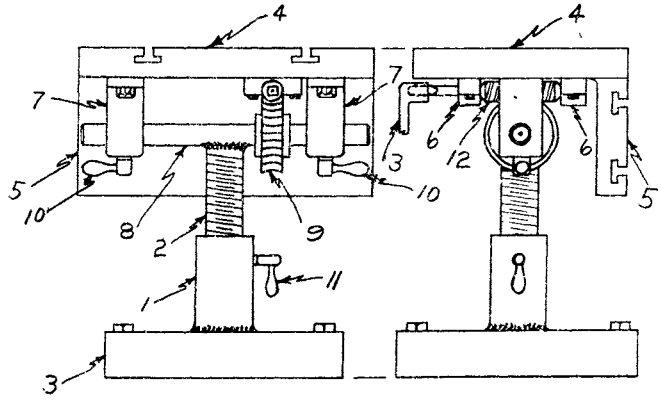


Fig. 4.2 A turn-table having means for tilting.

(1) Column (2) Elevating screw (3) Base plate (4) Table top horizontal surface (5) Table top vertical surface (6) Worm bearings (7) Horizontal shaft bearings (8) Horizontal stationary shaft (9) Worm wheel (10) Clamp lock, table (11) Elevating screw clamp (12) Worm (13) Crank handle

The table turns on bearings (6) and (7), on a stationary shaft (8), welded to the elevating screw. It can, therefore, tilt through 90° by revolving the worm (12) which is fastened to the underside of the table. The worm acts on the stationary worm wheel (9). Clamp locks (10), (11), prevent any movement of the table during the scraping operations.

This design has a number of points that are appreciated by the experienced scraper. In addition to the advantages mentioned previously, it is also very suitable for holding the always difficult "L" type castings, such as the knee members of milling machines. Furthermore, the tilting feature facilitates spotting and scraping the angularly inclined surfaces of dovetails and V-ways.

Sec. 4.7
Power Scraper

A power scraper is almost a necessity when considerable scraping is done in a shop. It will pay for itself very quickly whenever machine tools or production machinery are reconditioned in any quantity. The power scraper is one labor saving machine that is actually popular. It is appreciated by all users because it saves so much back breaking labor.

For straightening out a badly worn surface it is often speedier and more economical to employ the power scraper than to set up a planing or milling machine for a cut. This is particularly true if more than one set up is necessary to machine several surfaces. Although a piece of

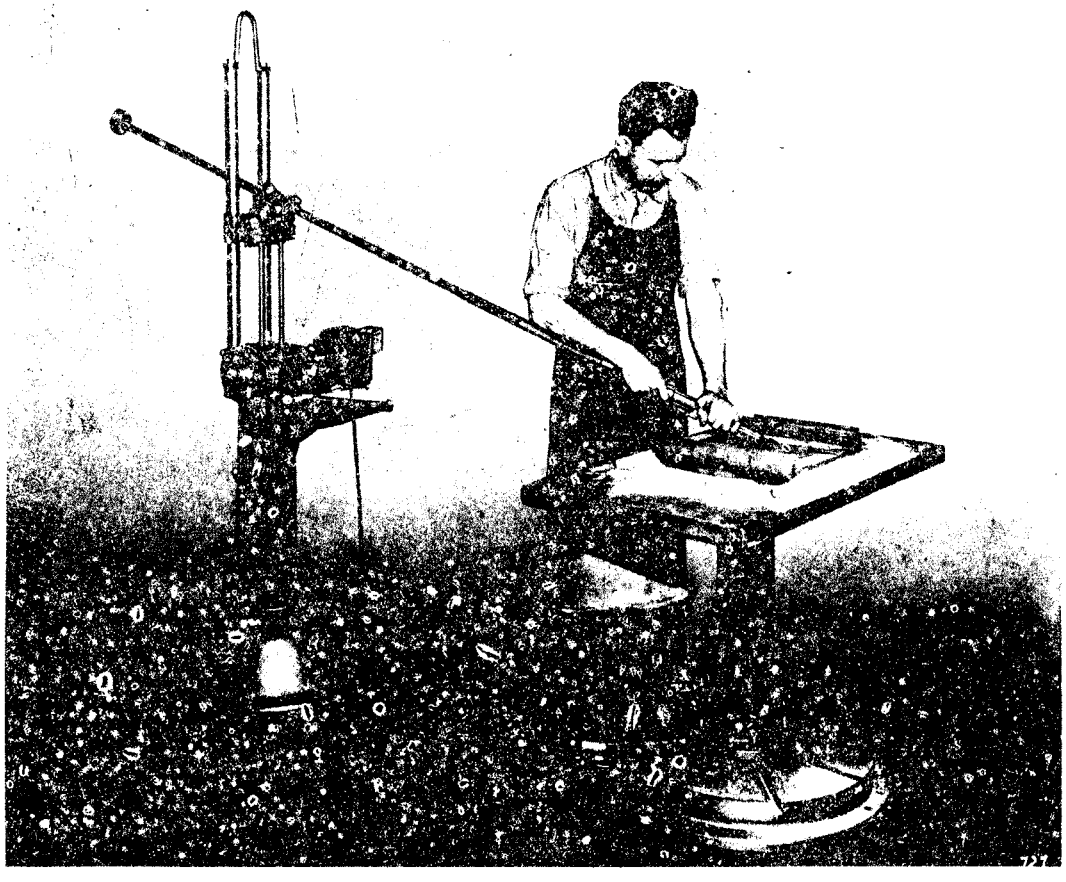


PLATE 1. Power scraper removing metal from work piece fastened to turn table. (Courtesy - Anderson Bros. Mfg. Co., Rockford, Ill.)

work can't be scrape-finished with this tool, nonetheless, in the hands of a workman of average skill, the surface can be reduced to an error of a few thousandths of an inch. The balance is then hand scraped.

The preparation for power scraping is very much the same as for hand scraping. Marking medium should be applied liberally as the work surface becomes quite rough, especially if long and deep strokes are made. This thick film will protect the spotting tool from scoring when indicating the high areas.

The method of using the power scraper is somewhat similar to hand scraping employing the body power stroke. When the blade is laid on the work, the left hand leads and serves as a guide for the blade. Pressure with the left hand controls the depth of the cut. The right hand supports the blade and controls the forward and reverse mechanism.

When the blade touches the surface, the operator immediately advances his right hand and the power stroke begins. The forward movement continues until the left hand eases the downward pressure and the right hand lifts the blade from the work. The forward stroke is checked in mid-air, as the right hand is pulled back. This causes the ram to reverse.

A few precautions are necessary when employing the power scraper, to prevent damage to the work piece. In the first place, it is best to anchor the work piece solidly so that it can't be pushed off the work bench onto the floor. This may happen if the blade is allowed to dig too deeply into the surface, or is not reversed in time and engages a shoulder. Another safeguard the beginner should take, in order to prevent possible damage, is short scraping strokes. Although the forward stroke can be regulated from 1/4 of an inch to three and a half feet, it doesn't pay to execute long sweeps with this tool unless there is a considerable thickness of metal to be removed. Even then this method should not be adopted by beginners for they are likely, quite innocently, to abuse the freedom of the method and inadvertently score the work piece. Shorter strokes interrupted by frequent spottings are preferable, as they enable the operator to scrape "straight down." This results in a smoother, straighter surface.

PLATE 2. Close-up of blade of power scraper applied to work surface. (Courtesy - Anderson Bros. Mfg. Co., Rockford, Ill.)

Power scrapers are constructed to swing laterally and the scraper blade holder is rotatable. The angle of the scraping arm can be increased or decreased with an elevating lever. These features adapt the machine to scrape surfaces at various heights and angles. They also make it possible to scrape extensive areas of the work before moving the machine.

When the scraping blade requires resharpening it is easily removed from the holder. It is sharpened in exactly the same way as a hand scraper blade.

It was not intended to leave the impression that the power scraper is unusually difficult to operate. While it is true that a novice's first attempt to use it is like having a bull by the horns and daring not to let go, yet after a little practice, excellent results are possible.

Sec. 4.8
Parallels

Parallels are units of standard equipment employed by scrapers, machinists, inspectors etc. Most modern tool rooms are equipped with several sets in various sizes. Essentially they are rectangular metal pieces having two opposite sides accurately finished and parallel. Sometimes all four surfaces are finished and opposite surfaces made parallel.

Speaking generally, parallels are divided into two main classifications; viz, Hand scraped parallels and Hardened and Ground parallels.

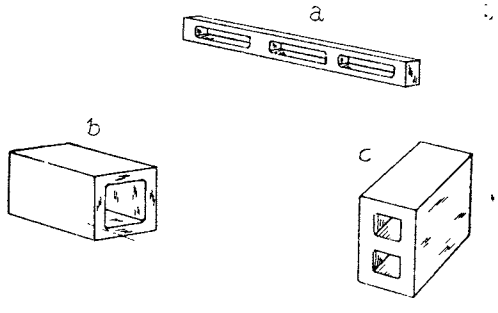


Fig. 4.3 Forms of Hand Scraped Parallels.
(a) Standard type (b) Box type (c) Box type

Fig. 4.3 shows a cast iron scraped parallel. This tool is cast, machined, and scrape-finished to SURFACE PLATE bearing quality. It is often cored to reduce weight and thereby facilitate handling. The accuracy of a scraped parallel can be checked easily by spotting it on a MASTER SURFACE PLATE.

Returning to Fig. 4.3 we see two types of box parallels. Usually these forms are so scraped that opposite sides are parallel and all four sides are 90^{o} to each other.

Fig. 4.4 illustrates a LEVELING STRAIGHT EDGE having parallel surfaces. This construction is suitable for bridging across a span of considerable width.

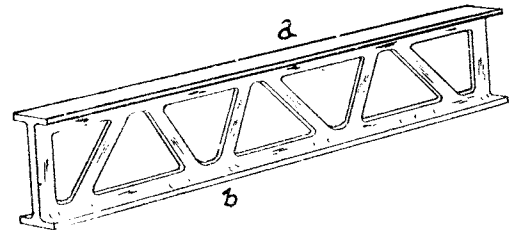


Fig. 4.4 Levelling Straight Edge. Surfaces "a" and "b" are scraped parallel.

PARALLELS also are manufactured from a special grade of tool steel, hardened and precision ground on all four sides. This type comes in various standard thicknesses, widths and lengths, and is regularly stocked by supply houses. These gages are used frequently in scraping operations for set ups and for inspecting and checking work surfaces in conjunction with a SURFACE PLATE.

The scraping operator also employs PARALLELS as bridges to span between surfaces too wide for the reach of ordinary tools. Other applications include building up from a surface of known flatness, supporting parts which have bosses or other projections that would prevent placement directly on a flat surfact etc.

A special utilization of PARALLELS is for extensions. For example, when a narrow bearing is being checked for parallelism with another bearing, there is sometimes not enough width or space to provide a fair sampling of the surface. By holding

a PARALLEL on the surface to be tested and them measuring to both extremities of the PARALLEL with a DIAL INDICATOR, a more accurate reading is registered. Fig. 27.12 illustrates an application of this method.

Sec. 4.9
Reconditioning Parallels

PARALLELS, like every type of tool, are subject to deterioration of one kind or another, though principally from shock damage. This is particularly true of the longer sizes. Since their usefulness is dependent on their accuracy, careful handling must be supplemented by restorative measures when warranted.

Restoring PARALLELS to their original first class condition is sometimes difficult. The hardened and ground type, for example, must be machined ground to extreme accuracy. The stumbling block here is that shops do not always have a surface grinder of sufficient size. Furthermore, these machines often have a tolerance of error that is excessive for this type of precision grinding. If the machine is somewhat worn, its accuracy although adequate for ordinary jobs, is hardly satisfactory for high class work. Consequently, reconditioning of a hardened and ground steel PARALLEL is often possible only by lapping which is a laborious and time consuming process.

For this combination of reasons, scraped PARALLELS are preferred by the scraping operator because he is able to preserve their accuracy with less effort. This is accomplished by utilizing a MASTER SURFACE PLATE for spotting, and by pin point hand scraping to eliminate the slight inaccuracies indicated.

When an identical set of three PARALLELS is required, the renovating procedure is the same as that used originally in generating them. This subject is discussed in Chapter 21.

Chapter 5

THE HAND SCRAPER

In this chapter we describe the tool used in scraping metal surfaces. Being relevant to the subject, the preparation of the blade for this duty is also amply discussed. Techniques covering both grinding and honing practice are included.

Sec. 5.1
Types of Hand Scrapers

One of the indispensable tools used by the scraping operator is the hand scraper. This tool somewhat resembles a cold chisel or a flat file. In fact many mechanics make their own scrapers from worn out flat files by grinding and honing an appropriate cutting edge on them.

There are two general types of scrapers for scraping flat surfaces, namely:

1. The flat scraper
2. The hook scraper

We are not concerned in this discussion with bearing scrapers or three-cornered scrapers for working curved bearing surfaces.

Hand scrapers vary in size from short 12" and 15" lengths to 20" and 22" sizes, and some are even longer. The blade may be 3/4" to over 1 1/4" wide and 1/16" to 1/4" thick. Individual preference determines the operator's choice of a hand scraping tool although most mechanics favor the short to medium lengths. Other dimensions are proportional.

Sec. 5.2
The Flat Scraper

The most frequently used kind of hand scraping tool is the flat scraper, known also as an "end scraper." When utilized to scrape a surface smooth and flat, the cutting edge of this tool is ground, then honed, to the correct shape by a technique fully described in a later paragraph. The flat scraper is also employed for producing various designs of frosting and flaking marks, but for these processes the cutting edge is usually ground and honed in special ways.

A detailed explanation of the correct method of handling a flat scraper, under different conditions, is given in other sections. Briefly though, the tool is pushed in scraping operations and either pushed or pulled for frosting and flaking, depending on the design required.

One of the more desirable qualities in the scraping tool is a degree of flexibility. (The care with which the blade was drawn when manufactured will determine whether this quality is present.) Springing action is conducive to scraping a smooth finish on the work surface. Elasticity also reduces scraping fatigue. Flexibility in the tool will promote the maximum efficiency in the body power stroke. With the arm powered scraping stroke, this characteristic is less important.

Sec. 5.3
The Hook Scraper

The hook scraper gets its name from the form of the cutting end which is bent in a short, sharp curve. A cutting edge is ground and finished by honing at the hooked end. With this form of tool the removal of metal is accomplished by pulling the blade towards the operator. This type of scraper is used mainly for flaking and frosting work, seldom for conventional scraping of flat surfaces.

For producing various styles of frosting and flaking, some operators favor the flat scraper and others prefer the hook scraper. Personal preference, rather than efficiency, is the basis for the selection.

Sec. 5.4
Commercial Makes of Hand Scraper Tools

Popular factory-made hand scrapers featuring replaceable cutting blades are

constructed with four component parts, namely:

1. The cutting blade, about 4" long, of special tool steel. When worn the blade is replaceable.
2. The shank, or main body of the tool.
3. The clamp, which fastens blade and shank together in a sort of splice.
4. The wooden handle, which fits on the end of the shank.

As the cutting blade wears it can be pulled out. However, not more than 1" should protrude beyond the shank and clip. A greater extension is not adequately supported and consequently there is a tendency to breakage under the strain of a deep scraping cut.

Sec. 5.5
Hand Made Types of Scraper Tools

Although commercial makes are popular, many mechanics prefer to make their own scrapers, either from flat files that have outlived their usefulness, or from flat stock tool steel. We will discuss the process of making a flat scraper from a worn-out file. Since considerable time and effort will be expended in converting a file into a scraper, it is only sensible to use good material to start with. The best assurance that the steel is the highest quality is to take a file made by a well known and reputable company.

Select a 12" or 14" flat file with fine teeth. A single cut smooth or double cut dead smooth file is best for the purpose. A fine tooth file is chosen because in grinding off the teeth, which is the first operation, we must remove enough metal to get well below any line fault developed while forming the teeth. Otherwise, the scraper may eventually break along this line.

Next the file is annealed. This is accomplished by heating the steel to a dark red heat, which corresponds to about 1300° F., and cooling slowly by packing in lime. The longer the period of cooling the more thoroughly the strains which were set up during manufacture will be eliminated.

The file is now shaped to the desired form by forging. This process requires it to be heated to a dull cherry red. Excessively high temperatures should be avoided as this tends to impair the density of the grain. (A charcoal or soft coal fire is preferred as a heating medium.) Naturally, there is a difference of opinion among machinists as to the most desirable form for a scraper tool. Some operators favor a file lengthened out so that it tapers uniformly from end to end. Other equally qualified mechanics prefer a tool having uniform thickness, except for a taper extending back about 3" from the cutting end. In either case the cutting end may be flared out or kept the same width as the body of the scraper, as desired. To produce a metal forging of fine texture, many light blows rather than a few heavy blows should be struck with a hammer preferably not exceeding 2 lbs.

CAUTION:

> If only part of the tool is forged, the entire piece should be annealed to remove the internal strains before hardening because the density of the metal as between the hammered and unhammered section will have changed.

At this stage of the work, consideration should be given to flexibility in the tool. The taper will influence this characteristic to a certain extent. For those operators who prefer springiness in their tool, the thickness of the steel may be reduced until the tank end is 1/8" tapering to 1/16" at the cutting edge. Some operators favor a stiffer scraper in which case the cutting end may be kept 1/8" thick with the tang end 3/16" to 1/4". The average width of the scraper will vary between 3/4" and 1 1/4". (Elasticity in the tool is a desirable quality, but what is best for one kind of job may not be suitable for another type of work. To permit a selection as needed, it is the custom of many operators to keep an assortment of several scrapers of varying flexibility.)

After the steel is forged to the shape desired it is allowed to cool, and then all hammer marks are removed by grinding. At the same time the ragged edges are smoothed off, forming a clean-cut, symmetrical shape.

The tool is now hardened by heating evenly and slowly in a coal fire until it is cherry red (about 1650° F.) The proper

quenching temperature is reached when small globules of flux or scale appear on the surface of the tool. As this point is reached the tool should be removed quickly and quenched in water or brine. If allowed to remain longer in the fire, pitting of the surface is probable.

Tempering is the next step. To prepare the tool for this operation it is polished all over using emery cloth. Next a film of machine oil is applied, the better to see the variations in color during the tempering process. The heat is applied to the tang end, and the tool is quenched at the moment the cutting edge reaches the proper drawing temperature. This is a matter of individual preference and may range from the glass hardness of an undrawn cutting edge to a light yellow representing a hardness of about 60 Rockwell.

Usually a wooden file handle is attached to the tang of the scraper, but since it is too pointed at the end to offer a comfortable rest when employing the body power stroke, it is customary to attach a circular piece of wood about 3" in diameter to the end of the handle to make bodily contact more bearable. Sometimes, in lieu of wood, circular pieces of leather, or heavy felt are attached.

In fashioning the wood handle for the scraper, an opportunity is provided to improve on the design usually found on these tools, even commercial makes. Some experienced workmen perform a quick "government job" on their tool, regardless of whether it is bought, made, or issued by the shop's tool crib.

After knocking off the slender wooden handle, a piece of hard wood is "turned up" to the size and shape of a door knob. Next a steel ferrule is forced over the small end, then driven on the tang. This knob handle design provides a comfortable grip for the hand and an easy rest for the body. It reduces fatigue in both cases.

Sec. 5.6
The Blade of the Hand Scraper.

Salient features of the blade are:

1. The breast. This has a slight bevel as illustrated in longitudinal section in Fig. 5.1a. When the blade is honed by hand the bevel degenerates into a slight curve as seen in exaggerated form in Fig. 5.1b.

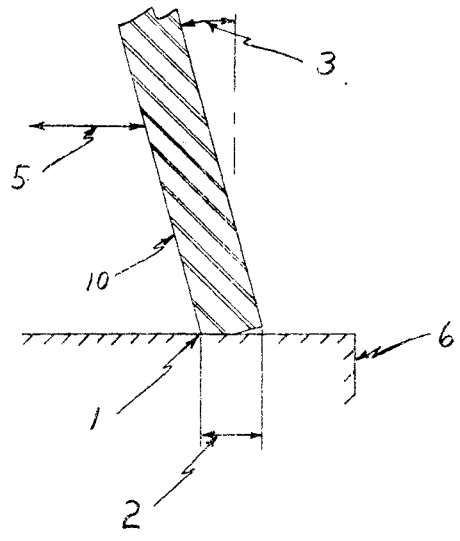


Fig. 5.1a Enlarged theoretical form of honed double edge blade. (longitudinal sectional view.)

(1) Cutting edge (2) Breast portion of the blade honed to provide cutting edge (3) Honing angle (5) Direction of honing stroke (6) Honing stone (10) Side of blade

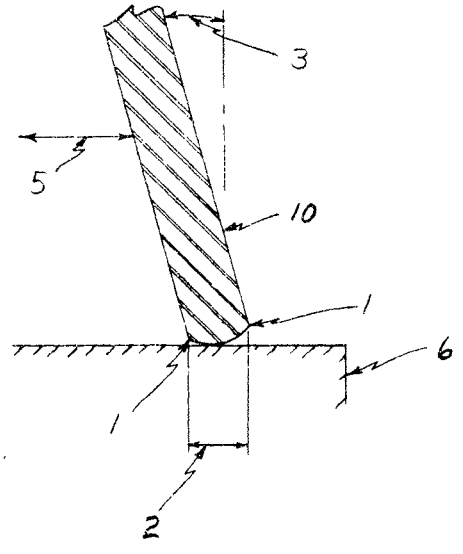


Fig. 5.1b Actual form of honed blade (enlarged) View through side of blade, longitudinal section.

(1) Cutting edge

2. The radial curvature. How this is produced is discussed later in describing the honing process. Fig. 5.2 shows a front view. The corners are chamfered and rounded in order to prevent

the tool from scoring the work piece if accidentally canted.

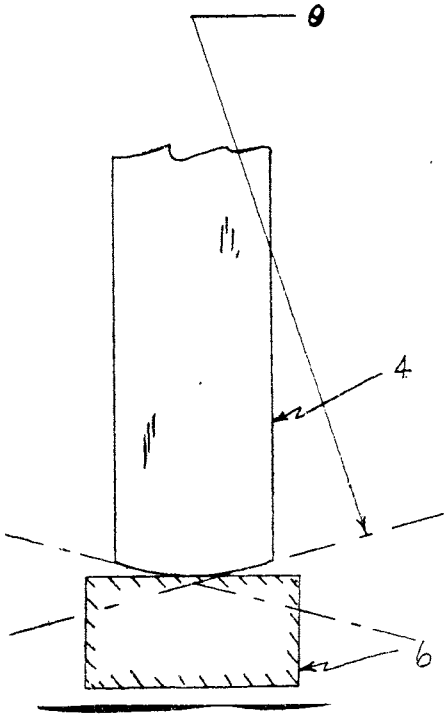


Fig. 5.2a Front view of scraper blade showing radial curvature caused by involuntary lateral rocking of tool during honing stroke.

(4) Flat of blade (6) Honing stone

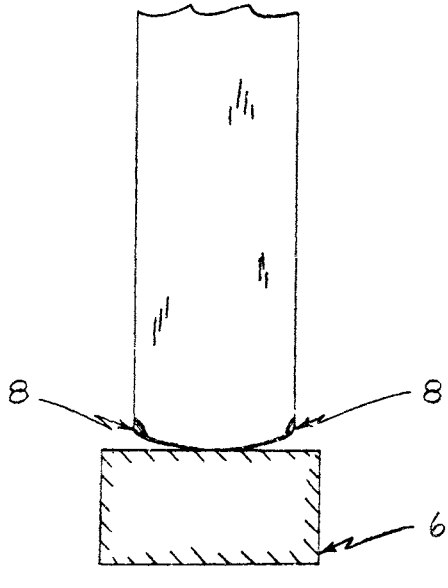


Fig. 5.2b Front view of scraper blade.

(6) Honing stone (8) Rounded, chamfered corners

3. The cutting edge is represented at work in Fig. 5.3.

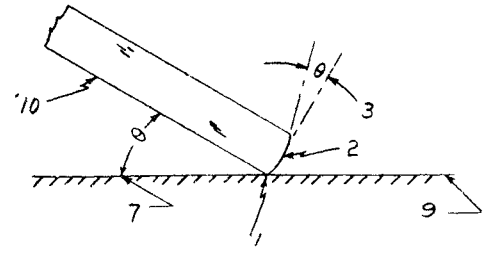


Fig. 5.3 Side view of scraper blade applied to a work surface and held at scraping angle.

(1) Cutting edge (2) Breast (3) Angle of honed bevel 0° to 30° (7) Scraping angle 10° to 30° (9) Work surface being scraped (10) Side of blade

Sec. 5.7
Sharpening the Blade

Sharpening the scraper blade is done in two steps. First, is grinding. Second, is honing. They will be discussed in that order.

We will assume that the steel blade is properly hardened and tempered. Commercial blades may be purchased in this condition. Since the basic principles of hardening and tempering steel are adequately treated in many technical books, no further mention will be made of that subject. It is enough to point out that the blade must be hard enough to keep its cutting edge over long periods of time, yet be tough enough so that the edge does not chip and break down easily.

Putting a cutting edge on a scraping blade is started at the bench grinder and must be done carefully. It cannot be emphasized too strongly that in rough grinding, the temper must not be drawn from the blade. Better still, the cutting edge should never be heated so that it becomes uncomfortably warm to the touch. If the rough grinding is properly done the first time, it need be repeated only at infrequent intervals as the blade wears down. Therefore, the few extra minutes spent in doing a conscientious job is time well spent.

Sec. 5.8
Grinding the Blade

The first operation is quite elementary

as the end of the blade, shown in Fig. 5.4,

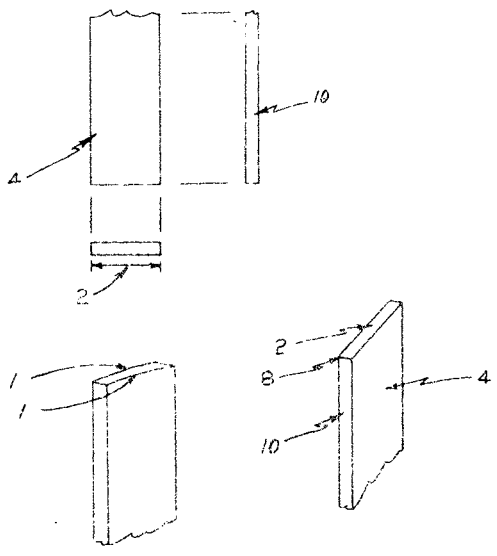


Fig. 5.4 Assorted views of end of scraper blade.
(1) Cutting edge (2) Breast (4) Flat of blade (8) Rounded corners of blade (10) Side of blade

is ground flat and straight across, transversely. For this operation an emery wheel of fine grit is employed. Selecting the proper abrasive will tend to reduce the depth of grinding wheel marks on the breast (2) of the blade. All of these must be removed by honing before the tool can be safely used. The blade is further inspected for pits on the flats (4). These pits when found in a commercial blade are probably due to improper heat treatment. In the case of the homemade tool, they also may be attributed to carelessness during the forging process. If either front or back flat of the blade is visibly pitted, this condition is rectified by additional grinding.

The preferred method is to press the flat (4) of the blade against the flank of the grinding wheel and burnish the surfaces, front and back, for a distance of about 1/2" to 3/4" back from the cutting edge (1).

Unless this grinding is properly done, the pits will survive the final honing on the flats. If a pit develops or emerges at the cutting edge of the blade, after a period of use, blemishes will be formed on the work piece by the blade during a scraping stroke. To the casual glance these blemishes appear to be scratches, but actually they are ridges. One tell-tale sign of poor, even amateurish work, is narrow ridge lines on the surface being scraped.

Finally, the sides (10) of the blade are touched lightly against the face of the wheel to knock off the large ragged fringes. A smooth surface on these sides is not required as they do no cutting. The practice of smoothing the sides is followed merely to give the blade a more finished appearance.

Sec. 5.9
Honing the Blade

After the breast of the blade is ground straight across and pits on the flats are no longer visible, it is ready for honing on the bench oil stone. Honing involves three steps, viz:

1. Polishing the flats.
2. Stoning the cutting edge.
3. Rounding the corners.

These operations will be discussed separately.

Sec. 5.10
Polishing the Flats

The honing operation is started by briefly rubbing both flats (4) of the blade on an oil stone as represented in Fig. 5.5.

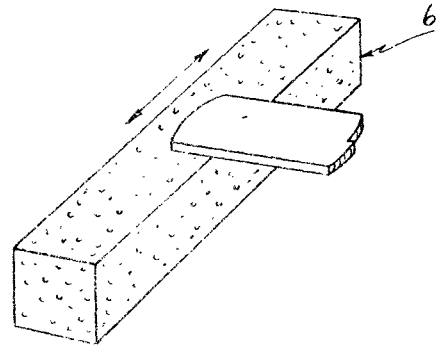


Fig. 5.5 Polishing the flats to prevent pits from forming at the cutting edge. Arrow shows direction of polishing stroke.
(6) Bench oilstone

This polishing is a rather continuous process and is repeated each time the cutting edge is sharpened. Over a period of time, a mirror-like finish is formed on both flats, extending for about 3/4" back from the cutting edge. Thus as the blade slowly wears down and new pits are exposed, polishing will eliminate them also by gradual stages before they become a danger.

Sec. 5.11
Stoning the Cutting Edge

There are two honing techniques for preparing a blade for scraping. The blade is stroked differently in each method.

Eight to ten strokes, in either case, are usually sufficient to produce a good edge. If two cutting edges are wanted (See Fig. 5.1b) the blade is turned half around and the action repeated. (In order not to disrupt the smoothness of the honing rythm, the turn is often executed with a quick snap of the wrist.)

In either method of honing the blade, only a reasonable amount of pressure is applied. Bearing down too heavily will cause the blade to be scratched. More force is exerted on the push stroke and pressure is eased up slightly on the pull stroke.

The honing techniques will now be discussed in detail.

Sec. 5.12
Honing (Method No. 1)

In this method, the scraper tool is held as steadily as possible either in an upright position or slanted toward the operator. This would be from 0^{o} to 30^{o} from the vertical. The angle selected will be determined by two considerations, namely, the hardness of the material to be scraped and the finish desired. Suggestions relating to this choice are discussed in a later paragraph.

The proper way for a right handed operator to support the blade is by gripping the shank of the tool with the left hand. The fingers are wrapped around the shank with the thumb extending vertically upward against the flat side of the scraper. The right hand grasps the scraper handle near the top. The flat side of the shank faces toward the operator during the full stroke, both forward and back, although for stability, the blade may be swiveled according to the operator's preference, but not more than about 25^{o} maximum. Essentially, this means that the cutting edge is not square to the direction of the stroke. Held in this way, the cutting edge of the blade is passed back and forth over the stone, as represented in Fig. 5.6. A rigid

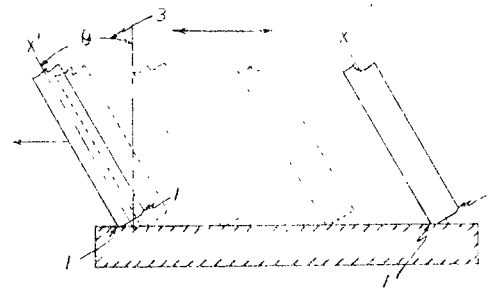


Fig. 5.6 Diagram representing motion of blade as it is drawn in towards operator as required by Honing Method No. 1.

(x) Position at start of stroke (x') Position at end of stroke (1) Cutting edge (3) Honing angle 0^{o} to 30^{o} inclination

arm position is maintained as the tool is alternately thrust away from, and then drawn toward the body, and so forth.

Theoretically, this honing movement will generate a bevel on the end of the scraper blade of from 0^{o} to 30^{o}. In other words, an angle of from 90^{o} to 120^{o} will be formed between the flat of the blade and the breast. Practically speaking, however, it is impossible to impart an exact straight line motion to the honing stroke. Instead, there is a slight involuntary wavering motion evident in the scraper blade in a direction parallel to the honing stroke. For instance, the operator may intend to hone the blade while holding it [illegible] from vertical but his inability to rigidly control the honing stroke will allow a variation of plus and minus of, say, 5^{o}. The result of this wavering is that, instead of producing a straight bevel, the breast is actually rounded. (See Fig. 5.1b) The curvature of the breast will be proportionate to the ability of the operator to keep the blade at a fixed angle to the stone during the stroke.

Since it is impossible to keep the hands exactly steady, a further modification of the cutting edge takes place as a result of

an involuntary sidewise motion.

These two forces act on the blade, as it travels forward and back the length of the stone, to produce a radial cutting edge, as represented in Fig. 5.2. This slightly curved edge is quite beneficial to the operator for reasons that will be discussed in a later paragraph.

With this method of honing the operator deliberately strives to support the scraper blade at one fixed inclination with reference to the stone during both the push and pull strokes. However, since the operator cannot hold the blade perfectly steady, the cutting edge will be formed by the combination of two forces, which are generated, namely:

1. There is an unintentional deflection of random proportion in the direction of the stroke which results in the formation of a slight convexity in the supposedly flat bevel being honed. This action by itself would form a straight though rounded cutting edge were it not for another factor, viz:
2. There is a slight, involuntary, sidewise wavering of the tool during the stroke which transforms the straight cutting edge to a radial cutting edge, as shown in Fig. 5.2a.

These two actions are simultaneous. Both of the curves thus formed are beneficial as will be shown subsequently.

Analysis of a newly sharpened blade reveals that the cutting edge forms at the dividing line where the straight, flat portion of the blade joins the bevel. Thus it would appear that since the breast is not utilized for scraping, it matters little whether it is rounded or beveled.

If a double cutting edge is desired, the blade is reversed and the procedure repeated on the other side. Fig. 5.1b illustrates the shape of the double cutting edge thus formed.

Sec. 5.13
Honing (Method No. 2)

The second method of honing varies from the first, in that the operator deliberately imparts a rocking motion to the tool during the push and pull strokes. During this action the position of the tool varies from the vertical, as the stroke begins, to a selected angle not exceeding 30°, at the finish. The choice of the angle is conditioned by the character of the work surface (hard or soft) and by the finish to be given it.

If right handed, the operator proceeds as follows:

The right hand grasps the scraper handle near the top. The fingers of the left hand are wrapped around the scraper shank near the end, the thumb extending vertically upward against the flat side of the blade. A rocking motion is given to the tool as it is pulled towards the operator and then pushed back. See Fig. 5.7)

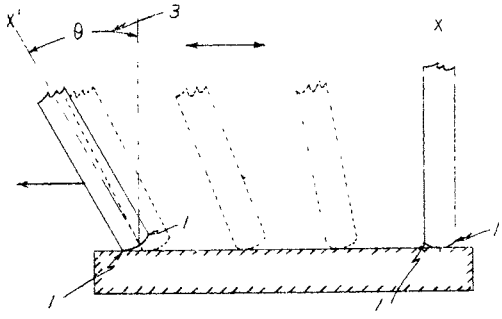


Fig. 5.7 Diagram representing rocking motion of blade as it is drawn in towards operator as required by Honing Method No. 2.

(x) Position at start of stroke (x') Position at end of stroke (1) Cutting edge (3) Maximum angle of rocking motion 0° to 30°

At the start of the stroke, the two hands are positioned one above the other, with the scraper tool held, let us say, vertical (0°). Then as the tool is drawn toward the body, the right hand (upper) moves faster than the left hand (lower). The pull stroke ends with the right hand closer to the operator's body than the left hand. Without changing the relative position of either hand, or lifting the scraper tool, the reverse stroke is begun at once. In this movement the tool is thrust away from the operator. The right hand (upper) again moves at a faster rate of speed than the left hand (lower) and both hands finish the stroke, one directly above the other, just as they were at the start of the initial stroke. In other words, on the pull, or forward stroke, the right hand advances faster than the left hand and the movement ends with the right hand ahead or leading. On the return stroke, the

right hand overtakes the left and both finish in position as they started, one above the other. Thus the blade is rocked forward and back, intentionally, and a curvature is deliberately honed on it. How curved the edge will be depends upon the degree of the arc through which the tool is rocked. That is, the tool may be held vertical as the stroke is started and have as much as a 30° inclination when the stroke stops. Or, for example, the start and stop angles could be 5° and 15° respectively leaving a net movement of 10°.

Due to better physical control it is easier to rock the blade while honing than to hold it in a straight line. Consequently, each time the blade is resharpened, using this technique, it is possible to obtain a very close facsimile of the type of edge desired. For example, if a cutting edge capable of removing large chips of metal is needed, the rocking motion imparted is slight. On the other hand, if an edge adapted to shaving off delicate flakes of metal is called for, the rocking motion required is considerable. In either extreme, or any intermediate case, the cutting edge can be duplicated very closely during the periodic resharpening process because it is not produced by a straight line motion, but by a curved line movement which is the more natural and automatic of the two methods.

With this process, as with the one previously described, an involuntary sidewise motion is likewise evident because it is virtually impossible to keep the hands in position one above the other during the oscillating (rocking) honing stroke. The slight lateral movement which develops in the right (upper) hand causes the blade to form a small radial cutting edge. (See Fig. 5.2)

Analysis of a blade honed by the method described above, reveals that in this case also the cutting edge forms at that line where the curve merges into the straight flat portion of the blade. Hence in either method the breast of the blade is curved; involuntarily, in the first instance; deliberately, in the second.

To provide two cutting edges the blade is turned front to back and the procedure repeated.

With either honing method, the purpose in view is to provide the most efficient cutting edge for any given work piece. This calls for some experiment and the novice when in doubt is advised that it is better to be conservative and keep the angle of inclination of the blade as small as possible i.e. close to vertical. Whether to increase it or not can be determined by the effect produced on the work surface by a few trial cuts. Should some modification be required, increasing the angle slightly at the next honing is a relatively easy matter. On the other hand, if the operator has erred in the first instance by honing at too great an angle from vertical, considerable surplus metal must be removed from the breast of the blade before its efficiency can be restored. In such a case it is often necessary to grind the breast flush with the cutting edge and begin anew. It is obvious that an error of judgment, such as this, is wasteful of both time and blades. A few suggestions on selecting the proper angle for honing are contained in a later paragraph.

Sec. 5.14
Rounding the Corners.

After a satisfactory keeness is acquired, the tool should be held at about a 45° angle to the oil stone. The four corners of the end of the blade are then rubbed a few times in a circular manner to round them slightly. This prevents scoring a work surface if the blade is accidentally canted during a scraping stroke.

Sec. 5.15
Advantages of the Radial Edge

The slight curve produced on the cutting edge by both methods of honing permits the blade to be used during all phases of a scraping job. That is to say, a blade with this form has the facility to pin point as well as scrape deeply. Moreover, by holding it at varying angles to the work in process, the width of the cut can be changed as needed. This convertibility is important because, as the high spots are reduced in size they increase in number, and must be picked off without impairing the surrounding surface. With the radial edge this can be done quite easily. To vary the width of the cut it is necessary only to increase or decrease the angle of the scraper tool with respect to the work surface and vary the pressure applied. In

this way it is possible to have at all times a blade proportioned to immediate needs.

Sec. 5.16
Selecting the Honing Angle

The type of work surface which is to be scraped is an important consideration when honing a cutting edge. It is a factor in determining at what angle the tool must be held to produce the best results. Although all metals can be successfully scraped, each has its peculiarities. Consequently, a blade suitably honed for one type of metal is seldom satisfactory for another kind until the cutting edge is modified.

Some experience is necessary to prepare a blade that will be ideally suited for fast scraping on a given job. Generally speaking, when the work piece consists of a hard metal it will be necessary to hold the tool closer to vertical when honing it than when preparing a cutting edge for application to a softer metal.

For example, the scraping tool that is satisfactorily honed for cast iron surfaces requires some modification of the cutting edge before it is equally efficient on semi-steel. When intended for application to a semi-steel surface, the blade should be honed at about 10° from the vertical. The cutting edge thereby produced is considered the best for this material. If the blade is held vertically and honed so that the cutting edge is flat across, it tends to hog in when applied to the work. On the other hand, if canted to an angle in excess of 10° when honed, the blade resists penetration into the work surface and additional pressure is necessary. As a general rule, the harder the metal, the closer to vertical the blade should be held when honed.

Another factor to be considered in honing the scraper blade is the degree of chill imparted to the casting to be scraped. Usually the thinner the casting the harder its skin. Consequently, for effective scraping on such a surface, the tool must be held more nearly vertical when honing it, than if the casting were large or massive, and hence softer.

The kind of finish to be produced on a work piece also influences the angle the tool is held when honed. As a rule, when honing a blade for finish scraping or pin pointing, it should be held in a position farther from vertical than when it is honed in preparation for a roughing cut. No hard and fast formula can be laid down and much depends on the skill and experience of the operator.

Sec. 5.17
Blade Assortments

Many operators who work regularly on different metals have assortments of either scrapers or attachable blades honed to various appropriate cutting angles. Since the efficient cutting angle for one type of metal varies from that required for another kind, and because rough scraping necessitates a different cutting edge than finish scraping, as we have explained above, therefore this practice might well be universally followed. Its principal advantage, of course, is the ready availability when a particular cutting angle is needed.

Another important benefit from this practice is that the individual blades will last longer. There is a sizeable loss in length in radically changing the edge from one cutting angle to another angle to accommodate dissimilar metals. If this alteration is made repeatedly, the wastage is high. On the other hand, when several blades are kept, each ground to a different angle, a slight change in one will usually modify it sufficiently so that it will be ideal for any given set of circumstances. This practice is simply economical management that will help the operator to conserve a favorite blade that cuts readily and holds its edge well.

Sec. 5.18
Care of the Hand Scraper

Hand scrapers which are forged and hardened from tool steel do not, unfortunately, all have the same ability to hold a cutting edge. Commercial blades ordinarily do have uniform quality and temper because their manufacture is rigidly controlled by a series of factory inspections. If occasionally, one is encountered that dulls rapidly, this may be due to improper initial grinding which impaired the temper. This is the fault of the first user. Experienced operators possessing a tool that retains a keen cutting edge will take every precaution to safeguard it, as it enables

them to do better work with much less effort.

Safe storage of the blade when not in use is very important. The cutting edge of a scraper blade is easily nicked, so the tool should not be tossed carelessly into a drawer containing wrenches or files. If it must be stored with a number of other tools, a leather guard should be provided to protect the blade.

Sec. 5.19
Carbide Tipped Scraper Blades

With the introduction of carbide tipped cutters to general machine shop use just prior to World War 2, it was only a matter of time before this material would be adapted to hand scraper tools. The innovation was accomplished by fastening small pieces of carbide to steel blades by a process such as silver soldering, or brazeing. At the time of writing, carbide tipped blades have been thoroughly tested and their qualifications adequately established.

Carbide tipped blades are preferred by machinists to blades of tool steel for some kinds of work. They will stand up eight to ten times longer than high speed steel blades when scraping hard materials. On certain surfaces, such as alloy bronzes, they are the only type that will cut successfully. In short, this innovation has earned its place in special scraping jobs, but has by no means supplanted steel blades for ordinary work.

The difficulty of sharpening carbide tipped blades with the equipment usually available in a machine shop is their one unfavorable feature. However, by providing the operator with access to a quantity of properly sharpened blades this objection loses much of its weight.

When necessary, these blades can be ground on special grinding wheels formed of carbide of silicon. This abrasive material is open and porous in structure insuring constant breaking action or resharpening of the wheel face. After grinding, it is necessary to finish each blade with a diamond lap because the cutting edge is invariably nicked or chipped in the grinding process. A diamond wheel also can be used for this purpose and it will provide a satisfactory finish. However, it is very difficult to form a clean cutting edge on the blade without a special set up, and the alternative, off-hand grinding on a wheel, is generally unsatisfactory. Therefore, if the blade is to be properly sharpened, it becomes necessary to use a diamond hone or a lap. A satisfactory cutting edge is acquired only by the personal touch, that is, with free and unhampered honing.

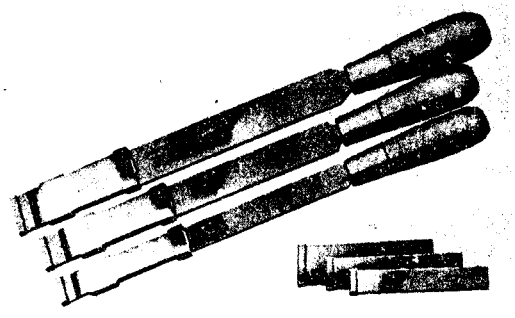


PLATE 3. View of three sizes of hand scraper with Carboloy Tipped Blades. (Courtesy - Anderson Bros. Mfg. Co., Rockford, Ill.)

We might conclude this subject by saying that if the material to be hand scraped is extremely hard or unusually abrasive, the use of carbide tipped scraper blades is recommended.

Chapter 6

MANIPULATING THE SCRAPING TOOL

In general there are two correct methods of using the flat hand scraper, each of which excels under certain conditions. Skilled operators use both techniques interchangeably as the nature of the work demands.

In addition to describing these strokes, this chapter will discuss the proper scraping methods under average conditions. These practices can be learned by experimentation, but the cost, particularly in time, is apt to be high. A careful study of how to cope with these situations, which are part and parcel of routine scraping operations, will prove profitable in the form of better work and superior speed.

Sec. 6.1
The Arm Power Stroke

In this method of scraping, the scraper handle is held by the right hand for pushing. The left hand grasps the shank somewhat below the mid-point and bears down. The scraper tool is usually held between a 10^{o} and 30^{o} angle with the work surface. Experienced mechanics who do considerable scraping are in general agreement that an inclination between these extremes is best for fast cutting without excessive gouging of the work surface.

The exact angle of attack is determined by the operator after a few tentative strokes. The smaller angle is favored for a keen blade because it cuts better when so held. As the cutting edge grows duller, the angle should be increased slightly to compensate for the decreased efficiency of the blade. When working on soft, tenacious metals, greater competence will be shown by holding the tool handle nearer to the work surface, that is to say, closer to horizontal.

With the arm power stroke the tool is thrust forward by effort of the arms alone. The hands serve to guide and direct the blade. Removal of metal takes place during the forward movement.

The muscular effort required of the arms, shoulders and back, combined with the necessity for simultaneous hand control of the blade, is undoubtedly fatiguing. It is the least desirable technique for sustained effort. Nonetheless, it is probably used more often than any other stroke because the work surface frequently cannot be positioned to accomodate to best advantage the alternative body power stroke. This is particularly true in machine tool reconditioning and repair wherein factory technique cannot be economically applied.

For scraping dovetails, V-ways etc., the arm power stroke is employed exclusively because the position of the work surface is seldom suitable for the alternative method. Furthermore, this method is the logical choice for pin pointing because the removal of metal must be delicately performed. Superior accuracy is the major consideration in such a case. The fact that speed is slower and fatigue greater is of secondary importance.

Incidentally, one adaptation of this method, applicable to the 20" - 22" length tool, is to hold the blade with both hands near the cutting edge. To steady the stroke the end of the handle is tucked between the arm and body.

With the arm power stroke the length of the cut seldom exceeds 1/2" and for the final pin pointing is but a fraction of that.

The path of the cutting edge as it penetrates the metal is a straight line movement. When momentum stops, the blade is drawn back over the work surface to a starting point for the next thrust. Whether this would be to the left or right of the previous starting position depends upon the placement of the colored markings. The tool is moved gradually from the far side of the work surface to the near side, or vice versa, depending on conditions which are discussed in a later paragraph.

PLATE 4. Hand scraping the base of a turret to fit the bed of a South Bend lathe. (Courtesy - South Bend Lathe Works.)

Sec. 6.2
The Body Power Stroke

The second method of hand scraping is known as the body power stroke. It takes advantage of the weight of the operator's body to effect the removal of metal. This method permits unhampered, two handed, directional control in guiding the cutting edge to the proper spot, as well as to the precise depth.

Using the body power stroke, the operator places both hands on the scraper tool in the following positions:

The right hand firmly grasps the tool shank at about the center with the fingers curled under the shank and the thumb extending downward. The palm of the left hand is pressed against the shank but closer to the cutting edge and then shifted up or down as conditions warrant. When the work surroundings are safe the fingers may be curled naturally. Otherwise, they should be stiffly extended. The left hand regulates the applied pressure which helps control the depth of penetration.

The butt end of the scraping tool is held against the body, usually the upper thigh or at the waist. The exact location is determined by the height of the work. With the body power stroke, the angle of the scraping tool in relation to the work is approximately 10° to 30°.

By swaying the body forward, the cutting edge is forced into the metal in an elliptical path. The movement is downward, forward, upward, and out. The carry-through of the stroke ends with the cutting edge of the tool above the work surface.

The blade is drawn back and again placed on the surface ready for the next thrust. This may be either to the left or right of the previous starting position

depending on the situation of the indicated high spots. The general direction of movement of the tool when employing body power, particularly on the initial cycles, is from the far to the near side of the surface.

The length of the stroke is governed by the condition of the work surface. If a considerable thickness of metal must be removed, the stroke is long, up to one or two inches. The depth is proportional and may be increased by applying more downward pressure on the tool with the hands. This naturally requires increased effort by the body to power the stroke. When the work surface is nearing completion the strokes are shortened, merging into light pecks with a decreased downward pressure on the tool. Thus merely the tips of the high spots are shaved off.

Sec. 6.3
Comparison of the Two Strokes

With the body power stroke, a uniform cut can easily be maintained over the entire work surface. But with the arm power stroke, uniformity is difficult to preserve over long periods of sustained effort because the arms must supply all the force behind the thrust and simultaneously guide it. In other words, the arms tire rapidly and are unable to deliver the cut with regularity as to length and depth.

Another factor that is important to consider when comparing the relative merits of the two contrasting techniques, is the speed with which a rough surface can be smoothed. An operator employing body power can remove with one stroke as much metal as an equally experienced operator can scrape in two, or three strokes, using the strength of his arms alone.

In general, both methods are accepted techniques in the metal working trades. The arm powered stroke is always utilized for the final pin pointing process and also whenever the body stroke is inconvenient to apply.

To achieve speed, uniformity of the cut, and reduction of fatigue, when scraping for prolonged periods, the operator will find it advisable to apply the body power stroke, whenever conditions are favorable. In scraping spacious surfaces, this method finds its greatest usefulness.

Sec. 6.4
Scraping in Unsafe Surroundings

When employing the body power stroke on a surface close by a sharp corner or edge, precautionary measures are called for to prevent injury to the leading hand, which will usually be the left. Instead of curving the left hand down and around the shank of the blade, as is normally done, the palm is pressed against the shank and the fingers are extended rigidly outward. In this way the operator is warned of the nearness of sharp projections by the sense of touch. Experience demonstrates that the rigidly extended finger tips will instinctively recoil as they lightly brush a projection thus warning of the proximity of danger. At this physical sensation the operator will shift his left hand.

This scraping hint is more than a little important, not only because it prevents some rather painful lacerations that occasionally are disabling, but primarily for a psychological reason. Considerable emphasis is laid on the necessity for the operator to keep "cool, calm and collected" and nothing is more likely to be upsetting than the probability of personal injury. Since the actual process of scraping is purely mechanical, anything that will relieve the operator of anxiety or worry is bound to be reflected in improved output.

Sec. 6.5
Routine of Scraping.

When starting to scrape a worn bearing surface, the strokes delivered during the initial cycles are longer and deeper than those employed when the finishing stage is reached. This is the correct approach to scraping since it is economical to complete a piece of work in the shortest time, provided of course, there is no sacrifice in quality. To accomplish the job efficiently, the work is roughed out. That is, in the early stages as much metal per cut is removed as possible. This fast scraping should not be tapered off until the markings show that the entire work surface has an approximately uniform, though superficial, bearing overall. When a fairly true plane is achieved, the length, width, and depth of the strokes is reduced.

It is understood that the initial roughing cuts are proportioned to the character of the work surface. The more worn the work piece, the more freely an operator may scrape when he starts a job.

If the blade is correctly honed and used, cutting may be practiced with greater freedom, and the appearance or finish of the work will be very little inferior to the quality of the final finishing strokes. When the work is done as recommended, the high spots will be lowered evenly over the entire surface.

The mistake of switching prematurely from rough scraping to finish scraping should, by all means, be avoided. Should this blunder be committed, the operator will spend considerable time pin pointing one section of the work surface while another portion may show only skimpy traces of marking compound, thereby indicating a negligible bearing. This makes for much wasted work which has only to be done over because neglected areas cannot be touched up independently of the areas of superior bearing without impairing flatness.

The scraping operator should never be reluctant to rough out ruthlessly, a fine finish immediately he discovers a low area not working into the over-all bearing surface. Failure to act decisively in such a case is, of course, only human because no one likes to destroy a fine appearing surface secured only after much hard labor. Nevertheless, situations like this often occur and leave the operator with but these two alternatives, viz: First, to begin over again and start right. Or, second, to putter along hoping for the favorable turn that never comes.

Sec. 6.6
Depth of the Scraping Cut

During scraping operations on, say, cast iron, the depth of metal per cut scraped from the surface will vary from .001" to about .0001". The usual depth of the cut is within this range when the scraping tool is powered by the body stroke.

(In cases where the scraping tool is powered by the arm stroke, the average depth of cut is somewhat less. For the final pinpointing of a surface, the depth of the cut may be as little as .00001".)

There are a number of causes influencing the depth of the cut. The most obvious, of course, is a change in tool pressure. A few of the other principal factors are as follows:

1. The type of material and the degree of surface hardness.
2. The design of the work piece and its placement for ease and naturalness of scraping.
3. The quantity of metal to be removed.
4. The keeness and cutting quality of the blade.

These major considerations and others of minor importance definitely affect the depth of the cut.

Sec. 6.7
Length of the Scraping Stroke

The length of the scraping stroke varies according to the method to be applied. Body powered strokes are 1" to 2" maximum, while arm powered strokes seldom exceed 1". These lengths would pertain to the initial cycles only.

As the work surface approaches the desired condition of bearing quality, shorter cutting thrusts should be taken. Shortening the stroke will promote the formation of a better bearing surface and also an improved surface finish. The length of the scraping stroke can be reduced by degrees until it is equivalent to the diameter of one high spot. This type of scraping is known as "pin pointing".

There is an additional reason for restricting the length of the stroke when we are scraping steel, or semi-steel. Long strokes have a tendency to produce deep scratches on these materials.

This penchant toward long strokes is extremely hard to resist when "roughing out" at the start of a rescraping job. Ordinarily, the bearing ways are oil soaked and slick from wear and resist penetration except when the initial starting pressure is heavy. Consequently, there is an inclination to keep the blade cutting, once started, thereby exaggerating the stroke.

Extended strokes, we know, induce scratches, perhaps because a metal particle adheres to the cutting edge. A dull blade will also scratch more perceptibly on a lengthy cut. Without theorizing

further as to causes, the evidence shows that no comparable blemish results from the ordinary scraping thrust of 1/4" to 1" length.

The characteristics of some metals enable them to withstand long strokes without disfiguring scratches, but others are quite susceptible. Any carelessness that results in scratches entails much extra effort and time to restore the appearance. The seriousness of such incidents can be minimized if the length of the stroke is proportioned to the characteristics of the metal.

The contention that long strokes save time has no basis in fact. Actually, time and effort are both materially increased as a result of this practice because the work piece is scratched more frequently and deeply. Removing the scratches often necessitates lowering the entire surface below the plane at which it could have been scrape-finished.

Sec. 6.8
Direction of the Scraping Stroke

If the body powered stroke is employed during the initial roughing cuts, the usual practice is to begin scraping at that point on the surface farthest from the operator, gradually approaching the near side. This procedure is followed to prevent pushing the debris forward onto other unscraped high spots, thereby partially covering and obscuring their size and position. It is particularly recommended for the preliminary scraping cycles when marking compound is liberally used and deep cuts remove large amounts of metal. (On soft cast iron, for instance, the size of chip removed per stroke may be considerable.)

The direction of the body power stroke during subsequent cycles is left to the judgment of the operator because progressively smaller quantities of shavings litter the surface.

On the other hand, when utilizing the arm power stroke, it is customary to work from the near to the far side unless the quantity of material removed is so large it obscures the high spots ahead of the cutting edge. Pin pointing is always conducted from the near to the far side.

As we have explained previously, the body powered stroke and the arm powered stroke are forward thrusts followed by a retracting movement to place the cutting edge to the side in position for another pass. Another type of stroking applicable to arm power requires a short forward thrust to be made. The blade is then pulled back a trifle and slid sidewise, which brings it to a starting point ahead and to the side of the initial position.

A series of such strokes comprises a chain moving at a tangent to the first thrust. When the chain is extended to a point beyond which it is inconvenient to continue, the scraper blade is returned to near the initial starting point in preparation for another series.

Sec. 6.9
Varying the Direction of the Scraping Stroke.

The direction of the scraping stroke affects to an important degree the quality of the surface finish. One of the peculiarities of scraping, familiar to all operators, is chatter marks. It is also known as wash board effect. This term needs no definition as its appearance is exactly what the name implies. Chatter marks are the result of pointing too many scraping strokes in the same direction.

To prevent chatter marks, the operator should on successive cycles vary the direction of the scraping thrust. That is, on consecutive cycles the direction of the strokes should be tangent to the previous cycle. How much of a change depends on a number of conditions. For example, on cast iron surfaces a shift up to a maximum of 90° is permissible. A shift of between 20° and 45° is sufficient to eliminate chatter marks for ordinary requirements. The characteristics of this metal makes such a procedure both possible and safe. On special jobs, where the most pleasing appearance is desirable, the direction of the scraping strokes in successive cycles, should be approximately at 60° to each other. This variation is usually sufficient to secure a good finish.

Ordinarily this 60° turn is made consecutively from three directions and then repeated. It will be found that the greater the number of shifts the more uniform the surface will appear. However, rotating the work piece through more than 180° improves the appearance little if any, regardless of how many changes in direction are made.

The softer metals and alloys, such as copper, aluminum, bronze etc. also require alternating the direction of the scraping stroke. To what extent can be quickly determined by the condition of the surface after a few cycles.

When working on steel surfaces a swing of 10^{o} to 45^{o} is about right. Steel is a most tenacious material to scrape. Exceeding the maximum suggested will only aggravate the difficulty and cause a scratchy surface besides raising large burrs and chatter marks. With a limited directional change in the thrust of the tool, it is possible to produce a smooth surface even on steel.

The design of the work piece also determines in large measure the procedure to be applied. If the construction is such that the operator can work on it equally well from all sides, we have the ideal situation. Usually, however, scraping can be executed only from one side, thereby restricting the freedom of movement.

On some jobs it is feasible to alternate the scraper tool, using first the right hand then the left hand to guide the blade. Substantially, the effect of this would be to alter the angle of the scraping stroke up to about 90^{o}. In all cases, it is inadvisable to scrape overly long in the same direction, as chatter marks are bound to appear.

To summarize: It is impossible to obtain a satisfactory surface finish on any kind of metal by scraping consistently in one direction. Therefore, the aim of the stroke must be shifted 10^{o} to 90^{o} on successive cycles, depending on the type of metal and quality of finish desired.

Sec. 6.10
Approaching the Edge of a Work Surface

The operator should strive to prevent the formation of chatter marks when scraping towards the edge of a piece of work. This can be done by directing the cut diagonally towards the edge, never parallel with it, and never broadside to it. It is also necessary, as we have explained before, to change the direction of the strokes on consecutive scraping cycles.

Another precaution is to avoid having more than a small part of the blade overhand the edge during a scraping stroke. If this occurs there is a natural tendency to cant the tool and gouge the edge. Needless to say this is a sign of poor workmanship. On jobs where appearance is of major importance, even one such careless pass can ruin the appearance of the piece beyond repair. On other work, whose requirements in respect to appearance are not so exacting, the slip probably can be overlooked, except that it denotes incompetence on the part of the operator. Literally thousands of scraping cuts will be made to finish a surface and it only takes one blundering thrust in the vital place to set at nought hours of painstaking effort. Extreme caution in scraping the edge of a surface is a fundamental axiom of the scraping art.

There is yet another factor the operator should take into account. Experience shows that as the scraping cuts are directed from the middle of the work surface towards an edge, a progressively deeper penetration is made, quite unconsciously. The effect is to induce the formation of a convexity in the central area of the work surface. Anticipating this, skilled operators make a deliberate effort to keep their thrusts uniform overall.

After the surface is scrape-finished the ragged edges of the work piece should be dressed. Filing a small bevel or flat of uniform width not only completes the job in a workmanlike fashion, it also guards against injury.

Sec. 6.11
Scraping the Perimeter of a Hole or Slot

When scraping a work surface which is slotted or drilled, it is best to direct the strokes of the scraper tool angularly towards the hole or slot. That is, the blade should never be thrust directly towards the axis of the hole. The correct approach necessitates a number of strokes converging on the hole from all directions as illustrated in Fig. 6.1. On the other hand, it is advisable to avoid guiding the tool around the opening. In other words, strokes circling around the opening, as shown in Fig. 6.2, may not only cause chatter marks, they may also produce a bevel.

Fig. 6.3 illustrates the right and wrong ways to scrape the edge of a slot.

Sec. 6.12
Off-Hand Scraping

When scraping operations are conducted

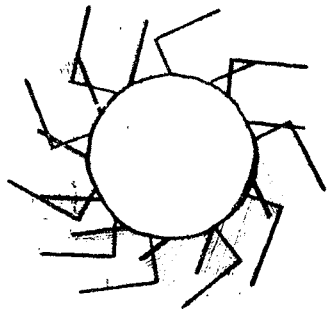


Fig. 6.1 Showing correct way to shave metal at lip of circular hole. To avoid rounding lip of hole do not let blade overhang too far.

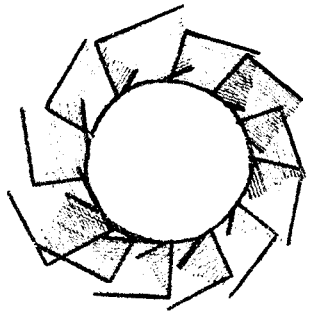


Fig. 6.2 Sketch of incorrect method of scraping around the circumference increase the likelihood of rounding off edges.

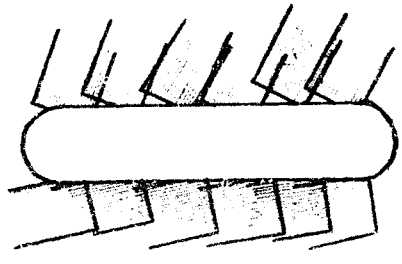


Fig. 6.3 (above) Correct method of scraping to edge of a slot. Strokes approach at a tangent.

(below) Incorrect method because all strokes parallel the edge. A rounded, or turned, edge may result.

with only a minimum of attention given to applying spotting tools, or making tests, it is called off-hand scraping. This method of scraping is particularly adapted to the initial roughing cuts. It is also efficiently employed at other times when the excess of metal to remove is considerable and when it is thought safe to scrape over the work surface a few times without alternate applications of marking compound. How often or how deeply to scrape, without follow-up checks with a spotting tool, will be, naturally, a matter of individual judgment.

There are certain hazards attendant to the adoption of the practice. A novice would be well advised to defer employing it until experience has been gained.

Sec. 6.13
Using Tool Marks as Guides for Off-Hand Scraping

It is seldom that a scraping operator will be confronted with the job of scraping a surface flat without the assistance of at least some kind of a spotting tool. Rare though such occasions may be, this adaptation of off-hand scraping still merits some attention.

A fairly satisfactory solution is possible, in spite of this handicap, when the work surface has been finished machined by a machine tool of known accuracy. Then in lieu of using a spotting tool to indicate the contour, the operator can use the tooth marks of the cutting tool as a guide. Each tooth of the cutter of, say, a vertical milling machine, generates tooth marks which vary in depth and appearance and therefore are distinguishable from the marks produced by other teeth of the same cutter tool. In other words, the scratch of each tooth can be traced unerringly across the work surface. Thus by utilizing as a guide the distinctive tooth mark of a certain individual tooth as it tracks from end to end of the work piece, a scraped surface can be produced whose flatness will correspond to the accuracy of the machine.

The technique is to scrape away the metal in such a way that the pattern of tooth marks formed by the milling cutter remains at an even depth below the plane of the scraped surface. On the first cycle, the entire surface is scraped over lightly to smooth the roughness. This serves to remove the faintest scratches. There now remains traces of several tooth marks which are deeper than any of those removed. Selecting the faintest mark as a guide the surface is again scraped all over to eliminate it wherever it appears. Then

the process is repeated using the next faintest mark, and so on, until finally on the last cycle the last visible tooth mark is removed.

If the operator will maintain a uniform pressure on the cutting blade with each stroke, the finished surface will be kept flat.

To assure that no part of the surface is missed, it is practicable to apply a thin film of marking compound over the entire surface and renew it at the start of each cycle. It is sufficiently transparent not to affect visibility.

Sec. 6.14
Comparison of Rough Scraping, Finish Scraping and Pin Pointing.

Like so many other shop expressions, the terms, rough scraping, finish scraping, and pin pointing are used loosely in the metal trades. Essentially, they all refer to the removal of metal chips by a scraping tool. It is the quantity of metal removed per stroke that creates the fundamental distinction of terms, not so much a difference in technique. Even with this definition there is no sharp demarcation because one classification merges imperceptibly into another. It is practically impossible to draw a hard and fast line between them.

Fig. 6.4 shows a profile illustrating the process of reducing surface irregularities into bearing spots as the scraping operation progresses by stages from rough scraping to finish scraping.

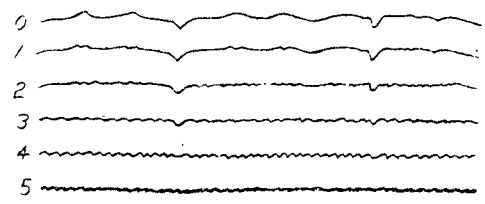


Fig. 6.4 Profile drawing illustrating the process of reducing surface irregularities into bearing spots as the scraping operation progresses by stages from Rough scraping to Finish scraping.

(0) Contour of worn surface (1) Contour after initial scraping cycle (2, 3 and 4) Showing progressive improvement resulting from intermediate cycles of scraping (5) Final scrape-finished surface

Note: It may surprise some readers to learn that a bearing surface is acceptable even though it is far from glass smooth. Ways and slides subject to reciprocating motion must not be too smooth or they will not maintain an oil film, and thus will fail in service.

For jobs specifying very close tolerances of surface finish it is advisable to measure the work surface with an electronic instrument. The advantages of this are two-fold. First, there is the assurance that the job will pass critical inspection. Second, there is no danger of overfinishing the surface.

Sec. 6.15
Rough Scraping

Rough scraping, also called "roughing-out", usually refers to the removal of metal at the start of a job. The main purpose of the initial scraping cycle is to reduce the rough or worn surface to a fairly flat condition in the minimum time. Consequently, the cuts are made longer and, coincidentally, deeper. As a natural result, not only are the high spots cut off but also part of the area surrounding them. How deeply the operator should scrape cannot be stated definitely as this is dependent upon the deterioration of the work surface, surplus thickness etc.

For example, if the work surface is badly worn, or has been roughly machined, considerable metal remains to be scraped away. In either of these cases, free cutting over the entire surface with long, wide, and deep strokes is the first operation undertaken. With each successive cycle, a shorter, narrower, and shallower cut is executed. When the surface has been developed to a condition that is fairly true, the rough scraping is considered completed and at this point, finish scraping begins.

Sec. 6.16
Finish Scraping

Finish scraping consists of improving a fairly flat surface into a final true bearing surface. The strokes used in finish scraping are short, narrow, and shallow in depth. These strokes, on the last time over the surface, merge into a mere pecking at the markings that shine. A proportionately smaller amount of metal is removed by finish scraping than in the rough scraping process.

The following table shows how a surface can be improved step by step. It will be noted that as the chip size is reduced the number of bearing spots increase.

Size of Cut (length x width)	Approximate number of bearing spots per square inch.
1/4" x 1/4"	8 - 12
3/16" x 3/16"	18 - 22
1/8" x 1/8"	30 - 35

When scraping an average surface an actual physical count of the bearing spots per square inch is seldom if ever made, except on SURFACE PLATES and STRAIGHT EDGES. The conclusions as to the bearing quality of a scraped surface are based on its overall appearance, as judged after a final application of a very thin film of marking compound with a spotting tool. The anticipated number of bearing spots per square inch may reasonably be expected by following the recommendations given in the table above.

It is easy to camouflage scraping marks, in which case the expected bearing quality will not be realized. However, we are speaking here of sincere efforts to produce a workmanlike job. In this connection, a method of judging bearing quality with reasonable accuracy is described in Sec. 22.19 Judging Bearing Quality.

Sec. 6.17
Touching Up

This is merely a continuation of Finish Scraping carried over into the field of fitting slides to ways. It is a desirable practice as it gives the newly produced alignment an added permanence. In other words, if the bearing quality is to be enhanced and the alignment stabilized, it is necessary for the various surfaces to be touched up before the machine tool is put in operation.

The reason for this statement can be better understood by considering the condition of a surface immediately following the final cycle of finish scraping. For instance, the bearing spots that have been formed by the scraping process are now all in one

PLATE 5. (#A74) Scraping work in process on a Cincinnati dividing head. The assembler is scraping one of the half-round clamps. Note in foreground the Arkansas honing stone in case. (Courtesy - Cincinnati Milling Machine Co.)

plane, as indicated by the transferred marking medium. Furthermore, since every effort was made to distribute them uniformly they will be well dispersed over the entire surface. These characteristics were developed on the final cycle as the surface was marked with a spotting tool. When using this tool it was necessary, in order to obtain a true picture of the surface, and to prevent distortion of the markings, to limit the rubbing movement to the shortest strokes of the minimum duration. If this is borne in mind, as well as the further fact that a film of marking compound served as a cushion between the two surfaces, it is quite understandable why additional treatment may be desirable after the two mateing members pass the alignment tests.

The alignment tests themselves may cause some alteration of the bearing spots. First, there is the weight of the more or less massive casting of the mateing member bearing down on them. Second, the film of oil lubricating the surfaces is much thinner and more easily ruptured than the coating of marking compound. Third, the alignment tests often call for sliding movements that are extended from a foot to several feet in length and, moreover, are frequently repeated. As a result, some bearing spots, which previously did not indicate their slightly greater height when spotted with marking medium, are now abraded and slightly worn down.

This has two immediate effects viz: First, the individual bearing spots broaden in area as the plane is lowered. Second, and more importantly, other spots previously at a slightly lower level come thereby into bearing contact. Thus the total expanse of bearing spots increases. That is to say, the trend is from bearing spots spaced singly to concentrated groupings of bearing spots.

On a dry or even a slightly oily bearing surface, these groupings of high spots display a distinctive coloration appearing as shiny black spots. They are clearly visible and easily identifiable.

Touching up the surface will consist of lightly scraping these shiny markings. If care is exercised and the very thinnest slice is shaved off, the alignment will not be affected.

This touching up process should be resorted to immediately after aligning each component having sliding bearing with another member. If it is conscientiously applied to each bearing surface, the machine will better resist the effects of sliding wear and consequently maintain for a longer period its proper alignment.

Sec. 6.18
Pin Pointing

Pin pointing refers to the removal of a single high spot with a calculated and predetermined stroke of the blade. In the scraping of precision gages, special attention is given to each imperfection. Its appearance, as judged by coloration, size, and position, will determine the pressure to be applied to the scraping tool. In short, pin pointing is the process involved in removing an individual high spot on work demanding highest accuracy and surface finish.

To summarize: rough scraping is the primary cutting of metal from surfaces sufficiently worn or rough to permit free strokes. Finish scraping refers to the final careful, cutting process which develops a fairly flat plane into a final true bearing surface. The pin pointing process extends into the field of precision tool manufacture.

Chapter 7

BENCH OILSTONES

Bench oilstones can be grouped in two general classifications: synthetic stones and natural stones. Each group may be further subdivided into a multiplicity of types. To discuss them all would undoubtedly be an interesting, though for our purposes, an unnecessary undertaking. Therefore, we will confine ourselves to a description of those kinds having specific interest to the scraper. The selection, use, and care of the stone is discussed solely from the standpoint of the scraping operator. These needs, it will be found, differ somewhat from those of the general machinist.

Sec. 7.1
Bench Oilstones: Synthetic or Artificial

The bench oilstone commonly employed for sharpening the scraping tool is an artificial or synthetic stone. To obtain the best results from these stones, there are a few things about them and their action upon metal surfaces that should be understood.

When selecting an artificial stone for the purpose of honing a scraping tool, an important consideration is the capacity of the stone to retain its surface in a flat condition. Even a slight amount of unequal wear in the artificial stone will produce an undesirable distortion of the cutting edge. Therefore, in making a selection of a bench oilstone, durability should be considered. Because they retain their shape and flatness longer under severe use, aluminum oxide abrasive stones are preferred by most scraping departments.

Another important reason for the popularity of this stone is the remarkable uniformity of the abrasive particles. Regardless of the type of grit, coarse, medium, or fine, the abrasive particles are of uniform size. This is important to the scraper because even one crystal, larger or harder than the rest, can nick his blade, thereby requiring expensive time to repair it. Medium grit, aluminum oxide stones are usually satisfactory for most work. The fine grit artificial stones are preferred for honing the very fine, keen edge required for some special scraping jobs.

Thus we see that in scraping work, aside from durability, it is uniformity of grit that counts, not its coarseness or fineness or sharpness. Incidentally, all coarse stones are not necessarily rapid cutting, nor are all fine stones slow cutting. Because silicon carbide is the sharper of the manufactured abrasives, such stones are usually found in the machine shop where fast sharpening of tools is desired, but in scraping departments such a characteristic has less importance.

Sec. 7.2
Bench Oilstones: Natural

Natural oilstones are often used for sharpening the scraping tools. Two natural stones in common use are the Wishita and the Arkansas. The first named is the coarser and more rapid cutting stone; the latter produces the better edge.

The Arkansas stones, coming in two grades (hard and soft) are the finest type of natural honing stone obtainable. According to geologists, the hard Arkansas stone (pure Novaculite) was formed by terrific heat and pressure, millions of years ago, when the earth's crust was molded. Although the colors range from clear white, to black and grey mixture, these variations do not affect the quality of the stone in the slightest. The hard Arkansas stone produces a superlative finish on the scraper blade. It holds its shape well even under severe duty.

Soft Arkansas stones are used where a very keen edge on the scraper blade is desired but where the exceedingly fine finish given by the hard Arkansas is not essential. Both types have an acutely

sharp grit and will cut and polish very hard metal.

In spite of being more expensive than artificial stones, as well as conspicuously fragile, the Arkansas stones are favorites with many machinists. They are preferred because they can produce a keen, smooth, super fine edge on a scraper blade. A blade having this characteristic is essential on jobs requiring a velvety finish on the scraped work surface. Incidentally, an equally good or even better finish may be had by using a cast iron, diamond imbedded lap, although such an extreme is seldom necessary.

Before putting a new Arkansas stone into service it should be soaked in oil overnight. Similarly before honing, it is advisable always to apply a light, non-gumming oil to the stone. The oil prevents the tiny particles of steel from loading the surface of the stone.

Sec. 7.3
Care of the BENCH STONE

All bench stones suitable for honing purposes are adequately protected if kept cased in a wooden box. A piece of oiled felt at the bottom will assure that the stone does not dry out. With the Washita and Arkansas stone this attention is almost mandatory because both are especially brittle and subject to breakage. Being expensive stones they deserve this extra care. A few drops of oil spread on the stone before honing will prevent glazing, but this should be a non-gumming and non-drying kind such as Pike Oil. In a pinch kerosene may be used. After using, the dirty oil should be wiped off with a clean rag or a handful of cotton waste.

Sec. 7.4
Renovating an Abrasive Stone

If the stone has become clogged with foreign substances it can be renovated by being heated in an oven or over a fire. When so treated it should be placed in a pan even if it seems dry, because a considerable quantity of oil and dirt will come out as heat is applied. Heating is continued as long as foreign matter is exuded. Then while the stone is still hot it is wiped with clean cloths. Following this treatment, it should perform practically as good as a new one.

A stone that is only gummed up can usually be restored to use by cleaning it with gasoline or ammonia. If more drastic measures are needed an abrasive cloth or paper can be employed.

In case the honing stone is worn appreciably, it may be straightened by rubbing dry on a cast iron plate into which are cut grooves, as shown in Fig. 7.1. To facilitate the process a handful of the grit particles removed by previous truings may be gathered and strewn on the C.I. plate. A figure eight (8) rubbing motion is adopted to smooth the stone. The work must be done carefully or a slight radius may be formed on the surface.

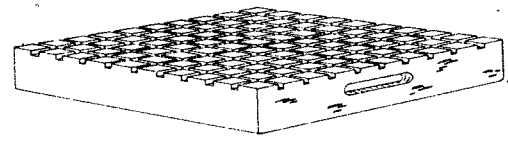


Fig. 7.1 Cast iron lap for smoothing and straightening bench oilstones. Serrations are milled in lap.

Another method of smoothing the bench stone is to clamp it in a vise and grind it flat on a Surface Grinder.

Sec. 7.5
Preferred Size of Bench Stone

In suggesting the ideal size of bench stone for purposes of honing, we cannot be specific. The only recommendation we can make is to use a stone of approximately the same width or a little narrower than the scraper blade ordinarily employed by the operator. There are two advantages in selecting this size.

First, there is assurance that the stone will wear down uniformly. A stone nearly equal to the width of the blade will retain its flatness indefinitely over most of its length. Only at the extreme ends, where the stroke is started and stopped, will there be a raised portion. Fig. 7.2 represents such a stone after long usage. Despite its appreciably worn appearance it is still capable of honing a sharp cutting edge.

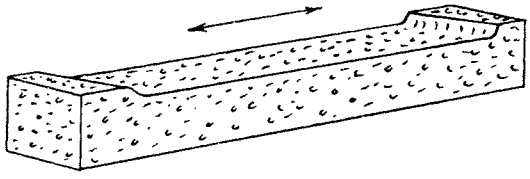


Fig. 7.2 Showing a bench oilstone heavily worn but still capable of imparting a keen edge to the scraper blade.

Second, a properly dimensioned stone helps materially in the formation of the very slight, radially curved edge so necessary in a correctly sharpened blade. This is explained in Sec. 5.11 discussing the honing stroke.

In practice, it will be found that a stone as wide as the blade will usually retain its flatness the full extent of the honing stroke. Experienced operators find that it wears down so uniformly that truing is seldom necessary.

The principal objection to using a stone wider than the scraping blade is that its surface wears down unevenly. Unless the stone is "trued" frequently, the cutting edge of a tool honed on it can assume any haphazard shape, though usually it degenerates into a pronounced radial curvature, or spade shape. Two effects of a pronounced curved edge on the tool are slow speed in scraping and inefficiency. Speed is slow because only a fraction of the edge is in contact with the work surface. Efficiency is impaired because the spade shaped blade naturally cuts deeper, thereby requiring extreme and tiring vigilance on the part of the operator to avoid gouging the work surface.

There has been considerable discussion of the width of the stone because it so vitally affects the cutting edge of the tool sharpened on it. The length of the cutting stone, on the other hand, does not influence the shape of the scraper blade honed on it. This dimension is not important, and the length is determined mainly by availability or convenience, although 6" is considered the practical minimum.

Sec. 7.6
Stoning Burrs

Another use of the bench oilstone in scraping practice is for stoning burrs. Before the initial application of the spotting tool, the machined work surface must be smoothed to remove, or blunt sharp projections and thereby prevent damage to the face of the tool. Similarly, after each scraping cycle, and before re-laying the spotting tool, the operation must be repeated.

The bench stone, either natural or synthetic, employed for reducing burrs on a scraped surface should be a fine grit type. Although such a stone scratches the work surface somewhat, it is usually satisfactory for average requirements, even in the final stages when the finish is quite velvety.

The choice of most scrapping operators, who use bench oil stones for smoothing burrs, is one with a knife blade shape. This form allows the stone to reach all the way into the hard-to-reach dovetails.

On the soft, malleable metals, such as copper, bronze, aluminum, and lead, a bench stone will glaze if rubbed on a burred surface. It is preferable, therefore, to employ other methods of dealing with troublesome burrs. For alternatives, refer to Sec. 4.1 on the Burr File and to Sec. 3.6 on the hardened steel block.

Chapter 8

THE SURFACE PLATE

The SURFACE PLATE is a precision tool used by scrapers to transfer marking medium to a work surface. As such it is a "standard of flatness." It is also used as a Datum Base for measurements involving inspecting and checking work when reconditioning machinery. In the manufacture of all kinds of tools, jigs, and fixtures, a first class SURFACE PLATE is a necessity.

This chapter describes the kinds of SURFACE PLATES and methods of caring for and using them in scraping operations.

Sec. 8.1
Types of Surface Plates

Three classifications of SURFACE PLATES are in general use, namely: cast iron or steel surface plates; glass surface plates; and granite or stone surface plates. No one type can be considered best for all classes of work as each excells under certain conditions. Their relative merits will be analyzed and the sizes, weights, accuracy, and other pertinent matters, fully discussed in subsequent paragraphs.

Before becoming specific, a few general observations would not be amiss. The SURFACE PLATE, whether metal, stone or glass, must have a very flat surface, yet it must not be smooth. Testing instruments, such as the surface gage, would stick to a slick polished surface and instead of sliding easily, would chatter.

Sec. 8.2
Cast Iron Surface Plate

The cast iron SURFACE PLATE is the standard of flatness for the scraping operator. There are several excellent reasons why it is generally favored for such a role, although for brevity a few will suffice. In the first place, the scraped SURFACE PLATE can be made as large as requirements demand. Secondly, it can be economically kept in accurate condition. Thirdly, maintenance can be performed by the scrapers during slack periods, right in the shop.

A cast iron SURFACE PLATE is a metal casting, usually of gray cast iron, or an alloy of the nature of semi-steel. The cast iron surface plates are commercially available in sizes from a minimum of 3-1/2" x 4" weighing about 3 lbs., to large plates of 3' x 6' weighing upwards of 1500 lbs. Besides many square and rectangular sizes, special oblong shapes having a width to length ratio of as much as 1 to 12, or more, may be obtained.

To provide a rigid base, enabling it to support heavy weights, the casting is well ribbed on the bottom. It is often supplied with leveling screws as well.

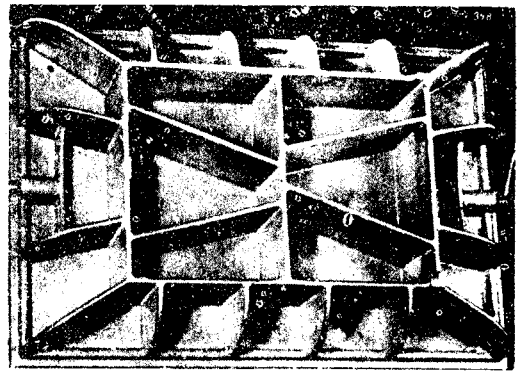


PLATE 6. View of bottom side of metal surface plate showing sturdy ribbing. Handles are attached at ends. (Courtesy - The Taft-Peirce Manufacturing Co., Woonsocket, R. I.)

The most important specification in a good cast iron surface plate, aside from flatness, is stability i.e , resistance to warping. To help produce this characteristic, the casting is rough machined, then aged, then finish machined and finally pin point hand scraped flat and true.

Painstaking care is taken to retard the onset of either growth or shrinkage which destroys the flatness of the plate. Ageing is by the natural time process or by low temperature annealing and alternate cooling to 120° below zero and drawing operations. Some of the smaller surface plates receive substantially the same stabilizing treatment given precision Gage Blocks.

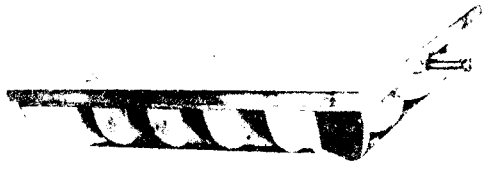


PLATE 7. Metal surface plate showing precision scraped top surface. (Courtesy - The Taft-Peirce Manufacturing Co., Woonsocket, R. I.)

In making cast iron surface plates, the simplest plan is to use a MASTER PLATE to "spot" the casting being processed. The surface is finally pin point hand scraped to obtain 30-35 bearing spots per square inch. Flatness is determined by a uniform coloration of the markings over the entire surface. It is essential to make an actual physical count of the number of bearing spots over a representative area of the top surface to verify the bearing quality. This is done by pencilling one inch squares along the edges, in the middle, and at scattered places across the surface and counting the bearing spots enclosed. (Flatness can also be checked with precision gage blocks or optical flats.)

Cast iron SURFACE PLATES in sets of three can also be generated from rough castings by applying the principle of the Symmetrical Distribution of Errors, which is discussed in Sec. 21.1. Since this is a rather extensive subject, it will be reserved for discussion in a later paragraph.

Sec. 8.3
Care of the Cast Iron Surface Plate

The care of the cast iron SURFACE PLATE is so important this subject cannot be overemphasized. Since the finished top surface of the PLATE is most liable to damage, the principal effort at protection should be directed to it.

Proper safeguarding of the SURFACE PLATE may be divided into two phases, namely:

1. In use
2. In storage.

When in use, the SURFACE PLATE should be handled carefully and never dropped or bumped. To lay cutting blades, files, or other sharp edged implements in contact is harmful to the finely finished surface. Before applying marking compound, wiping the surface of the tool with the palm of the hand will prevent stray particles of dust or grit from intermingling with the marking compound. It is equally necessary that the work piece be also scrupulously clean. If these conditions are observed, contamination is preventable. Otherwise, dirt and chips will be ground between the SURFACE PLATE and the work piece impairing the surfaces of both.

Another harmful factor which often causes the scraper much grief is burrs on the surface of the work piece. If any burrs are present they must be removed as they will most certainly scratch and score the fine surface of the tool.

As a final precaution, the operator should, at the end of each work day, cover the surface of the tool with a film of oil. If marking compound having an oil base covers the tool, it is considered sufficiently protected.

When placed in storage in the stock room, the SURFACE PLATE also requires some particular attention. To prevent warping do not place it in proximity to steam pipes, radiators, stoves, or furnaces. It is customary to protect it from rust by coating with oil or grease and providing a plywood cover. Besides being a good dust protector, the box shields the tool from sharp, pointed, or heavy objects carelessly dropped.

Sec. 8.4
Cleaning the Surface Plate

The face of the SURFACE PLATE is

always cleaned of its rust-prevention coating when it is removed from the stock room or tool crib and readied for use. The oil or marking compound, as the case might be, covering the surface is loosened with a solvent such as gasoline, benzine, or alcohol. A clean cloth is then rubbed over the PLATE surface removing the coating. Immediately, thereafter, the palm of the hand should be stroked across the PLATE to detect and remove stray particles of grit adhering to the surface or lint that may have shredded from the cloth. Only the bare hand is sensitive enough to detect all foreign matter on the surface.

Sec. 8.5
Testing the Cast Iron Surface Plate for Accuracy

From time to time, it is necessary to check the cast iron SURFACE PLATE for accuracy. To make such a test a MASTER SURFACE PLATE is relied on. This is a tool that is reserved solely for testing other SURFACE PLATES. As its name implies, it is of supreme quality, a worthy gage for precision tools.

When checking for accuracy proceed as follows: Clean thoroughly both the MASTER SURFACE PLATE and the PLATE being tested. Cover the surface of the tool being tested with a thin film of alcohol. After it dries, which takes but a few moments, a darkish film is formed. The microscopically thin coating constitutes the marking medium.

The reason that alcohol is used is that it leaves a dull back-ground against which the bearing spots stand out distinctly, thereby helping to register accurately the condition of the PLATE. Other marking mediums are not favored because they are relatively too crude, although Red Lead deposited by evaporation in a very thin solution is sometimes utilized for this precision test.

Now lay the SURFACE PLATE carefully on the MASTER PLATE. Do not slide it on. After a few slight push and pull movements, remove the SURFACE PLATE. Avoid sliding it off. Invert the tool and examine the numerous, small, shiny marks. If they appear to be uniformly distributed over the entire surface, continue with the test.

The next step is to lightly pencil a number of one inch squares over the surface at widely separated points. Distribute them to all four corners, the center portion and at scattered places. Cover ten to fifteen percent of the total area with these inch squares. Then count the number of shiny marks each square encloses. All should contain thirty, or more, by actual tally. If this standard of flatness has not been attained, the tool is not of sufficiently high quality to be considered a SURFACE PLATE. When a PLATE has thirty bearing spots per square inch, or better, over its entire area, it is considered A-1 and suitable for precision spotting work.

Sec. 8.6
Ground Surface Plates

In addition to production by hand scraping methods, metal SURFACE PLATES are sometimes manufactured by surface grinding. However, the shortcomings of the mechanical process limit the usefulness of such gages. In the first place, if large SURFACE PLATES are required it will be found difficult to produce and maintain them in a sufficiently flat condition with the equipment usually found in the average machine shop. Of course, if special machinery is available and is in first class condition, this objection cannot be raised.

Secondly, ground SURFACE PLATES do not transfer marking medium readily and are, therefore, restricted primarily to use as a measuring base or Datum Plane.

Sec. 8.7
Hardened Steel Flats

Flats are made of steel, hardened, ground, stabilized and lapped to obtain a very accurate surface. Necessarily, they are made in a small size which limits their usefulness to the scraping operator. Furthermore, being a lapped surface, they will neither "take" marking compound nor transfer it satisfactorily. Their chief use to the scraper is as a measuring base.

Steel flats are obtainable with an accuracy of flatness within 10 millionths of an inch per inch of length. They have a

surface finish of between 1 and 2 micro inches R. M. S.

Sec. 8.8
Glass Surface Plates

The Glass surface plate is a war baby developed during World War No. 2 to offset a serious shortage of metal surface plates. Since their introduction they have attained a widespread use and popularity.

Glass surface plates range up to 18" square for standard sizes. Special sizes and shapes may also be procured. Thickness varies between one and two inches.

Two types are made; solid one-piece and laminated. The one-piece glass surface plates are manufactured from heavy polished plate glass or from structural glass. The latter does not have the clear, high surface that is characteristic of plate glass. The laminated glass surface plate which has a high resistance to fracture, is made from numerous layers.

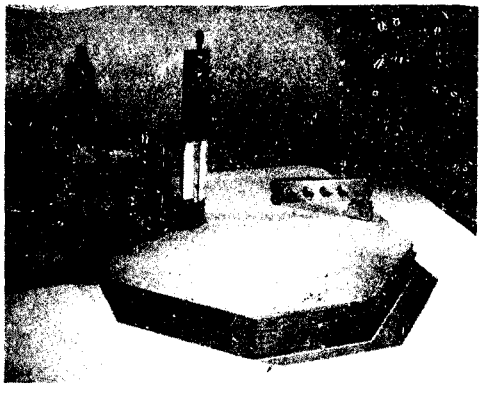


PLATE 8. Close-up of Profilm Laminated glass surface plate consisting of numerous layers of glass. Fine ground surface accurate to within .00005". (Courtesy - The DoAll Company, Des Plaines, Ill.)

Glass surface plates have a number of advantages over metal or cast iron surface plates and also over stone surface plates. One important advantage is that glass has a very low co-efficient of expansion and is less affected by temperature changes. Therefore, it will not warp as easily as a cast iron plate. It is impervious to body heat.

Glass surface plates can be used for either spotting or reverse spotting. They are light in weight compared to either metal or stone surface plates and prove less tiring to the operator who works with them. Although not provided with handles, holes may be drilled for this purpose if desired.

Some types of glass surface plates are transparent, allowing instructions or data to be placed underneath for ready reference.

Being a hard, non-porous, dense material, glass does not absorb oil or other matter and is easily cleaned of any gummy formations by wiping with a cloth soaked in solvent. It will not rust and is not subject to corrosion as a result of acid on the operator's hands. Glass plates do not require oiling before putting them in storage.

Glass is subject to scratches, but these do not affect accuracy unless grouped densely. Even when hard objects drop on a glass surface plate, burrs are not formed. While small chips may be actually removed by the force of the blow, the remaining surface is still in a perfect plane. The surface does not become warped due to this peening action and no burrs are raised to destroy its accuracy. Glass surface plates are, therefore, very durable.

Surface plates made of glass are produced by a grinding and polishing method. During the grinding operation the surface can be given a very fine, uniform "roughness" which will "take" a marking compound. Another characteristic of this "roughness" is that it prevents a vacuum from forming between the plate and a tool being used upon it. This feature is necessary so that tools and gages will not vibrate or "chatter" while being slid. Another method of eliminating vibration consists of etching lines in the glass with acid. The lines formed by this process do not affect the accuracy of the plate in anyway.

Glass surface plates can be checked with a master optical flat and monochromatic light. The accuracy is determined by the number of Newton rings visible. For some types a uniform overall accuracy of from .0002" to .0005" is standard. Others have an accuracy as high as .00005".

Sec. 8.9
Granite Surface Plates

Granite surface plates are another comparatively new development in the [illegible] trade. Their growing importance justifies a discussion of their advantages, particularly with respect to scraping operations. They are adaptable to both spotting [illegible] and instrument testing.

In the period [illegible] hundreds of different types of stone have been experimented with and approximately six kinds have been found [illegible] surface plates.

PLATE 9. View of 8' x 16' Granite surface plate showing lapped surface. (Courtesy - The Herman Stone Company, Dayton, Ohio)

The rock is quarried from strata, millions of years old, which has not been subject to stress.

Consequently, when sawed to size, from the small 2" x 3", all the way up to the large 8' x 16' dimensions, the blocks have no internal strains. Unlike other materials which are "cast", the granite plate has no tendency to warp.

The fine surface is produced by a lapping process. A 2' x 3' size can be finished to an accuracy of .00005". On the larger sizes a tolerance of as little as .0002" overall can be obtained. Certain types of this stone can be finished to a finer degree of accuracy than any other known material. Since granite plates can be finished in such large sizes with precise accuracy, they are ideal to use for checking the alignments of large and heavy machine members and other work pieces.

This material is rust-proof and corrosion-proof and does not require oiling or any kind of special protective covering.

Marking compound, metal particles and foreign matter are easily cleaned from the surface without impairing accuracy. Granite surface plates are naturally non-abrasive and there is no danger of impregnating them with grit.

Granite is notable for its great hardness and resistance to chipping. Even the hardest blow from a falling object will not cause dent burrs to form on its surface.

PLATE 10. Showing method of using Granite Surface plate as a Datum Plane. (Courtesy - The Herman Stone Company, Dayton, Ohio)

Having a natural porosity of approximately one per cent (1%), which is sufficient to provide the necessary break in the air seal, granite allows smooth operation of the various gages without chatter. Freedom of movement is such that a dial test indicator of ten thousandths sensitivity can be used at the top of a 24" height gage without vibration. Gage blocks will not wring to the surface.

Granite plates are non-magnetic and therefore it is unnecessary to demagnetize the work before placing it on the plate.

In the matter of weight there is not much difference between granite and cast iron surface plates. Consequently, reverse spotting is entirely feasible. For an 18" x 24" plate, the stone weighs 160 lbs., while iron tips the beam at 143 lbs.

Since the surface is very durable and resists wear and even abuse, there is little reason to make frequent checks for

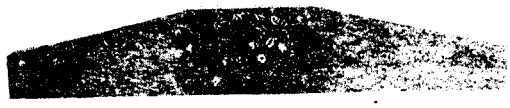


PLATE 11. View of Granite Straight Edge. Rigid handles can be attached for pushing or lifting. (Courtesy - The Herman Stone Company, Dayton, Ohio)

flatness. The plates cannot be tested by placing optical flats on the surface because they will not wring and therefore light bands are not formed. Should a granite plate become damaged it must be returned to the manufacturer who has proper facilities for refinishing it.

Sec. 8.10
How to Use the Surface Plate to Transfer Marking Compound

There are two possible ways to use the SURFACE PLATE so as to indicate the surface bearing quality of the work. One method is known as reverse spotting. It is performed by placing the tool on the work surface. This system is applied when the work piece is large or otherwise difficult to handle.

The other method is called spotting. In this process the work piece is placed on the tool, which implys that it is small and convenient to manipulate. The precautions to be taken with both arrangements are very much the same as will hereafter be explained.

While not technically correct, the term spotting is often used interchangeably in the machinist's trade for both techniques. The alert reader will note that this practice is also followed in this book.

Sec. 8.11
Reverse Spotting with a Surface Plate

The first step in reverse spotting procedure consists of applying marking compound to the surface of the tool. Details of this work are described elsewhere.

The second step is to lay the SURFACE PLATE on the work. Never slide it on the work piece, and when removing it, do not slide it off. It should be lifted by its handles to a point over the work, then lowered straight down. To remove the SURFACE PLATE, lift it directly up.

There is only one exception to this rule and it pertains as much to spotting as to reverse spotting. For example, when using a liberal quantity of any marking medium having an oily base, the oily nature of the paste helps create a suction which is sometimes difficult to break by lifting directly off. With some marking mediums, such as Red Lead, this characteristic is not so pronounced. However, faced by such a predicament, the only recourse of the operator is to slide the upper member off far enough to break the suction, then lift it up. Such a practice can be tolerated because it will be used only at the start of a job when the film of compound is thickest and accuracy requirements least exacting.

After the SURFACE PLATE is placed on the work, it is rubbed back and forth, four to six times to transfer the marking medium to the high spots on the work surface. This movement is accomplished by grasping the tool, with one or both hands, at one side only. The fewer the rubs and the shorter the movement, the more accurate will be the results because less marking medium is stripped off. Thus the quantity of compound which can be forced by PLATE pressure into low areas surrounding the high spots is reduced.

The shortest length of movement, say one or two inches, and the application of the thinnest film, minimize the tendency of the marking compound to smear. As experience is gained it becomes less and less a problem to guard against this.

It is always inadvisable to force the PLATE downward by hand. The resulting pressure causes the marking medium to run more than it normally would, thereby exaggerating the size of the markings. Some operators are inclined to do this when working with the smaller and lighter PLATES. It should seldom be necessary to apply any pressure to the PLATE. Usually the weight of the tool alone is sufficient to transfer the compound adequately to the work surface.

In selecting a SURFACE PLATE, the best choice is one as nearly equal to the size of the work surface as possible. The necessity for this is explained in detail in Sec. 9.9.

The actual manner of handling the SURFACE PLATE is another important factor in accurate reverse spotting. After the operator has laid the PLATE on the surface of the work piece, he selects the most advantageous side of the work from which to push and pull the tool. After each scraping cycle the operator returns to this selected position and again applies the tool.

When speaking here of the advantageous side, we do not refer to such things as lighting, nearness, convenience of position, or any factor which could be altered or eliminated by a mere rearrangement of fixtures, tool, stance etc. What is meant by "advantageous" is the selection of that side of the work from which the operator may most speedily reduce the work surface to flatness. How to choose the most advantageous side and the reasons for the choice, are discussed in detail in the Sec. 11.7 on Stabilized Conditions.

Sec. 8.12
Spotting with the Surface Plate

Spotting is the term applied to the method of transferring marking medium by rubbing a work piece back and forth on a SURFACE PLATE. Whenever this procedure is utilized, the work piece preferably should be of a size and weight, convenient to handle. The technique is to coat the surface of the PLATE with marking medium and then put the work piece on top. In laying the work piece on the PLATE, it is positioned directly without sliding. And after spotting, it must be removed in a similar manner, again without sliding. For the purpose of motivity, the hand, or hands, are always placed at one side of the work piece. The side selected should be the most advantageous for stabilizing the markings. For reasons refer to Sec. 11.7. As cycle follows spotting cycle, the procedure described above is repeated without change. Although this scrupulousness may seem unduly fussy, it is surprising how much trouble even a slight deviation can cause.

Sec. 8.13
Duration of Spotting

Elsewhere we have discussed the reasons for restricting the movement of the spotting tool to the minimum length necessary to transfer the compound. Closely allied to this, but more insidious in its effect, is the error of prolonged rubbing. A spotting cycle should be limited to four to six back and forth movements of the tool.

It is a human failing to hope that the surface being spotted will show a good bearing. To achieve this condition, the mechanic often is inclined to rub the tool overlong on the work surface, even if he does not otherwise improperly handle it. While the results may be visually gratifying, this procedure will not produce accurate spotting.

All marking mediums, bluing especially, tend to ooze out under the effects of pressure generated by spotting. The flow is into surrounding low places. The effect of this is falsely to indicate a high spot where actually none exists. Another unfortunate consequence is to strip away from the tool some of the marking compound which should remain in place. Due to excessive rubbing a particular high spot may come in contact with a much larger area of the tool than would be the case with normal manipulation. In this way it will accumulate around itself an excess amount of marking medium thereby giving a completely erroneous impression of the condition of the bearing surface.

Different effects from protracted spotting are noted when Red Lead deposited by evaporation on a work surface and then marked with a clean tool is employed as the medium. Oozing would not be so noticeable with this less oily compound although the high spots indicated by brownish or blackish markings would increase slightly in area. The more probable result of excessive rubbing is scoring of the spotting tool. (With an oil base marking medium, such as bluing, that hazard is less likely but is still possible.)

The degree of movement of the tool and the time it remains in contact with the work surface should both be kept to a minimum. These safeguards, combined with proper handling of the spotting tools, will assure accurate markings.

Sec. 8.14
General Instructions for Spotting

1. Excessive hand pressure on the work piece is as detrimental to good spotting

as is pressure on the SURFACE PLATE during reverse spotting.

2. It is preferable to have the work piece nearly equal in size to the tool. However, if the tool is much larger, the work piece may be rubbed on a different portion of the surface at each spotting. By thus shifting the work piece around, no one part of the SURFACE PLATE receives excessive wear and its accuracy is maintained longer. Another reason for using a PLATE approximately equal in size to the work, is to discourage any tendency to long sweeps when rubbing. The movement ought to be restricted to one or two inches in length. Unless unavoidable, the work piece should never be larger than the SURFACE PLATE because accurate spotting is very difficult under such conditions.
3. It is advisable always to level the SURFACE PLATE before placing any work on top. Otherwise, there is a danger of warping the tool, especially if the work piece is heavy. PLATES are sometimes equipped with adjusting screws for this purpose.
4. Allowing direct sunlight, particularly in the summer time, to strike one end or side of a Cast Iron SURFACE PLATE is detrimental to accuracy because that part will expand disproportionately to the remainder.

Sec. 8.15

Q. What are the disadvantages of using a SURFACE PLATE of incorrect size, that is, one considerably larger or smaller than the work piece?

A. The first objection that comes to mind is that if the SURFACE PLATE is much larger than the average work piece handled, it costs more to keep in good repair than one of correct size. The second drawback is that wear is not uniform, leading to accelerated deterioration. Even if some effort is made to distribute wear by rotating the rubbing from place to place, it cannot be wholly successful. Moreover, it tends to distract the scraper's attention from more important matters. A third disadvantage is that inexperienced operators, using such a PLATE are prone to make long sweeps which lead inevitably to false markings.

On the other hand, when the SURFACE PLATE is much smaller than the work piece, there is always grave doubt as to the accuracy of the markings. The reason is that the PLATE, in these cases, merely rides up or down following the contour of the worn surface. Either a concave or convex surface could develop, and still the markings transferred by the tool would indicate flatness. Such a PLATE will generate markings which seem to denote that a surface is flat even when its convex or concave characteristics are quite pronounced.

When the only SURFACE PLATE available for the job is undersized, it is standard procedure to make alternate applications of a STRAIGHT EDGE of adequate length. In this way the shortcoming of each is overcome.

Chapter 9

THE STRAIGHT EDGE

STRAIGHT EDGES may be divided into three general classifications, as follows:

1. The hardened steel straight edge
2. The standard STRAIGHT EDGE
3. The ANGLE STRAIGHT EDGE.

These tools and their various applications will now be described.

Sec. 9.1
Hardened Steel Straight Edge

This type of straight edge is part of the scraper's complement of tools. It is a highly accurate gage having hardened and ground edges. The tool is made in various sizes but scrapers find the 20" length most suitable for general work.

The hardened steel straight edge is used mainly for checking the flatness of machined surfaces. It is particularly effective in checking ground surfaces which cannot be successfully indicated by marking compound. (Marking compound will not transfer readily to or from ground surfaces.)

Successful utilization of this tool depends on critical judgment based on either the sense of sight or the sense of touch.

A person with average vision can see light through an opening .0001" wide. Consequently, by placing the EDGE on the surface being checked and sighting toward a good light, it is possible to determine if the surface is flat.

The exact amount of deviation from flatness cannot, however, be ascertained by sighting. For this reason testing by the sense of touch is often preferred. The Three Paper Method is widely used in this connection. Refer to Sec. 22.4. In some cases Precision Gage Blocks are substituted for the paper strips.

Sec. 9.2
The Hand Scraped Standard Straight Edge.

For spotting purposes on planer, lathe and grinder machine beds, and other comparably long surfaces, the pin point hand scraped STRAIGHT EDGE is essential scraper's equipment. It is a precision tool in all that the term implies. The STRAIGHT EDGE shown in Fig. 9.1 is made with a truss section for maximum rigidity thereby maintaining accuracy. The sides are cored to reduce weight. This design is best adapted to retain a straight edge - flat surface.

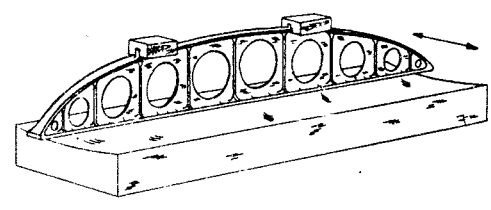


Fig. 9 1 Markings produced by a transverse movement of a narrow STRAIGHT EDGE on a wide surface are not absolutely reliable as a concave (or convex) condition would not be detected.

Manufacturers stock these tools in sizes that range from 18" x 1 1/2" weighing about 5 lbs., to the large 10' x 2 3/4" dimension weighing approximately 300 lbs. Even longer and heavier ones are made to order.

STRAIGHT EDGES are commonly manufactured from grey cast iron, or steel alloy. Mechanics planning to make their own should be apprised that they are more difficult to construct than the SURFACE PLATE. For instance, equivalent care must be given to stabilizing or ageing the casting. Machining operations must be performed on sturdy rigid fixtures and careful attention given to prevent springing. The same painstaking care extends to scraping when that operation is begun. The holding fixture should be designed to preclude any tendency of the STRAIGHT EDGE to warp while it is being pin point hand scraped. It is standard practice to test the surface of the STRAIGHT EDGE

for flatness by means of a MASTER SURFACE PLATE or MASTER STRAIGHT EDGE. Incidentally, it is possible to generate these precision tools by the Three Plate Method utilizing the principle of the Symmetrical Distribution of Error. (See Sec. 21.5)

As a final detail, two wooden handles are attached to the curved arch of the STRAIGHT EDGE. They are used to make easier the lifting and placement of the tool on the work piece. When actually manipulating the tool for spotting purposes they are seldom touched. Most experienced operators prefer instead to grasp the iron frame at the end of the tool. This is considered better practice because it makes for more accurate spotting.

Handling the Straight Edge

The STRAIGHT EDGE is one of the two principal spotting tools utilized by the scraper, the other being the SURFACE PLATE. Accurate information on how to handle the STRAIGHT EDGE will improve the technique of the operator and make for greater efficiency and more dependable markings. The recommended procedures are as follows:

Sec. 9.3
Correct Handling in a Horizontal Position

After applying a film of marking compound to the STRAIGHT EDGE place it carefully on the work surface. Then grasp either a handle, or the frame at one end, using only one hand. Move the tool back and forth on the work about four to six times. Meanwhile apply just enough pressure to the gripped end to keep that end of the tool in contact with the work surface. Any tendency of the gage to teeter-totter on a convex surface is thereby overcome. The weight of the tool does the actual spotting; the hand merely overcomes the instability and provides the motive power.

On a concave surface, or on a relatively flat surface, the weight of the tool alone is sufficient to spot the work. Little or no hand pressure is called for as the tool shows no tendency to teeter in such cases.

When accurate directional control is necessary, both hands are used. The guiding hand is placed on the tool, slightly ahead of the propelling hand. One hand may hold the handle while the other grasps the frame at the usual end position.

If there is danger of the tool sliding off the work piece, only one hand should remain on the tool to propel it. The other is touched to the work surface or adjacent thereto for guiding purposes. A finger, or the thumb of the guiding hand, is extended so that it bears against the lower side of the tool. Incidentally, the heat of the hands on the tool for the short period while spotting the work, will not impair the accuracy of the markings.

The length of movement of the tool, back and forth, should be the very minimum. One or two inches is usually sufficient and gives a more accurate spotting than a longer stroke. An extended motion strips larger quantities of marking compound from the tool, causing it to flow off the high spots into adjacent low areas. This tendency to run is more noticeable with bluing than with red lead.

The tool must never be manipulated by holding both handles, or opposite ends, at the same time. If this improper technique is used, even a slight downward force, imposed simultaneously with each hand, will cause the tool to bend. The STRAIGHT EDGE is designed to resist any deflection due to its own weight, but with additional pressure, the tool sags and thereby loses its accuracy.

Even if no pressure is applied, manipulation with a hand grasping each end of the tool is still objectionable because it induces a teeter-totter effect. The STRAIGHT EDGE will ride up one side of a contour and down the other side producing markings that seem to indicate an apparently flat surface. Unfortunately, these indications will be inaccurate and cannot be relied on.

To re-capitulate:

1. Keep the tool in contact with the work only long enough to transfer the marking medium. Usually four to six to and fro movements will suffice.
2. Move the tool the minimum distance, one or two inches.
3. Manipulate the tool from one end only. Do not see-saw the tool with a hand placed at each extremity.
4. To avoid false markings, allow only the weight of the tool to do the spotting.

Any hand pressure applied should be just sufficient to keep the manipulated end in contact with the work at all times.

5. Always take a stance at the most advantageous side of the work piece. This subject is discussed in Sec. 11.7.

Sec. 9.4
Correct Handling in a Vertical Position.

Spotting is much more difficult when conditions require the STRAIGHT EDGE to be held vertically than when positioned horizontally. Accordingly, it is preferable to set the work piece in the horizontal position whenever possible. Frequently, however, the STRAIGHT EDGE must be applied to work not so conveniently located. In such circumstances the recommendations in the following paragraphs are pertinent.

The correct way to support the weight of tool on a vertical surface is from the lower end with one hand. The other hand is placed no farther up than is necessary to steady the tool and to transfer the marking medium with a light pressure. This pressure should no more than equal what the tool itself would normally apply, if it was in a horizontal position. How much this might be is, of course, a matter of individual judgment developed by experience. The movement of the tool, while rubbing it up and down, should not exceed the customary one or two inches.

A very prevalent error, when spotting with the STRAIGHT EDGE held in a vertical position, is to grip the tool at the lower end, meanwhile grasping the upper end with the other hand. Demonstrably, this is the most convenient way to hold it. But whether convenient or not it is the wrong method of support because the same common error is committed. In short, the hand pressure at the extreme ends, either bows the STRAIGHT EDGE, or induces a teeter-totter effect when it is moved back and forth on a convex surface. As a result false markings are inevitable.

Sec. 9.5
Handling the Large Straight Edge

For the accurate spotting of the ways of planer, lathe and grinder beds, a STRAIGHT EDGE is indispensable. If the machine is of large size, the spotting tool must necessarily be of considerable length. Some made-to-order STRAIGHT EDGES attain a length of 180" x 3 1/2" width. The weight in such cases runs upwards of 800 lbs. These very heavy types are usually lifted onto the work piece by a chain hoist and lowered into position. Removal is by the same means. It is obvious that utilization of such a tool calls for somewhat different spotting methods than described heretofore.

When a STRAIGHT EDGE is too heavy to be handled capably by one operator alone, an assistant can be used with good effect. The operator takes a position at one end of the tool and pushes and pulls in the customary manner. Meanwhile the assistant stations himself at the far end of the tool to guide it. If the work surface is sloping, he also supports the tool to prevent it from sliding off. While so acting, the assistant should not apply pressure to his end.

When the STRAIGHT EDGE is too heavy for the operator to move by himself, he needs another helper at his end of the tool. The tool should always be manipulated from just one end.

Handling from both ends after the fashion of two men using a lumberman's saw is improper technique. Detection of a convex surface is made difficult as the STRAIGHT EDGE will ride up one side of the contour, tilt when overbalanced, and then slide down the other side. Long strokes with the tool simply make matters worse.

Sec. 9.6
Utility of the Straight Edge

In spotting surfaces of broad area.

There are occasions when it becomes necessary to scrape some piece of work of broad area, using only a STRAIGHT EDGE for applying compound. For example, assume a work piece size 30" x 30" must be scraped flat and that the only spotting tool available is a STRAIGHT EDGE, size 36" x 2".

In these imaginary circumstances it will be found that there are two principal obstacles to overcome if accurate work is to be performed. First, difficulty will be experienced in spotting a uniform film of compound with the undersized tool. Much can

be done to minimize this factor if a spotting procedure similar to the following is adopted.

1. The STRAIGHT EDGE is coated with a suitable medium and laid at one end of the work surface. Then it is rubbed lengthwise with a slight reciprocating motion. Simultaneously, it should be pushed slowly sidewards, all the way across the work surface. On alternate spotting cycles, the direction that the tool is pointed is changed by 90° to prevent the formation of concavity or convexity.
2. When the work surface is very large and the tool comparatively small, as described above, the quantity of compound available on the tool may be insufficient to cover the work uniformly as it is pushed from one side to the other. When the scraper experiences difficulty in spreading uniform films, it will be necessary occasionally to remove the tool and rework the compound. More compound is added to it when needed. The tool is then relaid on the work surface at the point of removal and the spotting cycle is resumed. Circumstances sometimes favor spreading the marking compound on the work surface. Spotting is more accurate with this arrangement. If this alternative process is adopted, there is no change in the manner the tool is manipulated.
3. Another measure which can be practiced with good effect is for the operator to alternate the direction from which the freshly coated tool is pushed. That is to say, while conducting the to and fro movement, the operator should propel the tool from right to left for one spotting cycle; shift by 90° for the second cycle as described in #1; return to the initial stance for the third spotting cycle, but this time propel the tool in the opposite direction, that is, from left to right, and so on. In the long run, this will equalize the quantity of film applied over the entire surface. Since it is obvious that the portion of the surface first spotted will receive more compound than other areas spotted thereafter, any means which will average out the over-all distribution of compound will ensure greater accuracy.

The second obstacle mentioned above is the fact that the undersized tool produces markings which cannot be completely relied on, particularly in the initial stages of the job. Consequently, during the early phases it is advisable to supplement the procedure outlined above with the following routine.

4. After the STRAIGHT EDGE traverses the work, the surface reveals a pattern of markings. These are carefully noted on the Markings Chart (See Sec. 11.8) as a memo of the first spotting.
5. The entire work surface is wiped clean. No scraping is attempted yet because, while the markings may be true indications of high spots, they may, on the other hand, be only half true or even wholly false.
6. Compound is again applied to the tool (or work). The STRAIGHT EDGE is placed in position. This time, however, it is moved across the surface in a direction 90° to the first application. The sidewards movement across the work is accompanied, as usual, by a short to and fro rubbing action.
7. On completion of the second spotting, the location of the marks on the work surface is penciled on the Markings Chart.
8. A thoughtful analysis of the Chart will provide the clue to the character of the surface. The true high spots being now indicated can be scraped down.
9. The Markings Chart can be dispensed with when the work surface becomes reasonably flat. The processes of spotting and scraping are continued as long as necessary.

Sec. 9.7
Utility of the Straight Edge

In gaging surfaces narrower and longer than the tool.

Sometimes the work surface is longer, but narrower, than the available STRAIGHT EDGE. When this situation prevails, the following method will produce satisfactory results.

1. The STRAIGHT EDGE is coated with marking compound. Then it is laid at one end of the work surface. A slight reciprocating motion, lengthwise, is

given to it (about one or two inches)
2. After removing the tool, the location of the markings should be sketched on the Markings Chart. (See Sec. 11.8)
3. The work surface is thoroughly cleaned; no scraping is as yet undertaken.
4. Next the film of marking compound on the tool is reworked, more being added, if required. The tool is relaid on the work surface, but this time from the opposite end. It is pushed back and forth briefly, as before.
5. On removing the STRAIGHT EDGE, the location of the marks is penciled, for the second time, on the Markings Chart.
6. No scraping is attempted; and the surface is cleaned of marking compound.
7. After the usual preparation, the gage is relaid on the work surface, midway between each end. It is rubbed a few inches in either direction and removed. (This operation may be dispensed with if the two previous lays overlapped by a reasonable amount.)
8. The marks showing on the work are again recorded on the Chart
9. By analyzing the penciled records and keeping in mind the various positions occupied by the tool, a clear picture of the condition of the work surface will be readily apparent. Not till then may the operator safely proceed with the scraping.
10. A new Markings Chart will be made for each of the next several spotting cycles or until the true condition of the work surface is fixed in the operator's mind. It may then be dispensed with. The spotting technique is, however, continued with those variations thought best, until the scraping process has produced an acceptable bearing surface.

Superficially considered, this routine might appear to be "Much ado about nothing." The experienced scraper, however, knows that it is foolish, even dangerous, to begin scraping before a complete and accurate picture of the entire surface is obtained.

As more fully explained in Sec. 11.8, on Markings Charts, a marking indicated on a certain area, under some conditions, does not necessarily represent a high spot. Usually it does, but sometimes it is questionable and at other times it is obviously and totally false. Consequently, to avoid scraping low spots even lower, thereby exaggerating the difficulties of the job, it is best to proceed in the manner just outlined. With care, the operator can produce a flat bearing surface, in spite of the handicap of inadequate tools.

Sec. 9.8
Spotting an Inverted V-Bearing Surface With a STRAIGHT EDGE.

Accurately spotting the sloping sides of an inverted V is a difficult procedure since part of the weight of the STRAIGHT EDGE must be supported by the operator at the same time he is transferring the compound. The situation is improved somewhat if the bearing surface can be positioned so that it is approximately horizontal. Unfortunately, this is not feasible in most cases.

The probability of accurate spotting is enhanced if the STRAIGHT EDGE is slightly longer than the work piece. However, since conditions are not always ideal, it might be well to outline an acceptable procedure for a case where the STRAIGHT EDGE is shorter than the work surface.

We will assume an imaginary case wherein a three foot tool is used to spot a four foot long inverted V. The proper utilization of a short STRAIGHT EDGE on an inverted V that is longer is to lay the tool from the end towards the middle and transfer the medium with a short movement of 1" or 2". (See Note) The other sloping side of the inverted V is treated in like fashion.

After memorizing the location of the markings, the surface is cleaned. Then the spotting is repeated, but this time the tool is laid from the opposite end toward the middle. As before, both inclined sides of the inverted V are dealt with successively. The four consecutive spottings should provide a good idea of surface conditions despite the several handicaps under which the operations are performed.

To aid the apprentice in avoiding pitfalls it may be well to describe a spotting procedure that is definitely bad practice. For instance, with the work surface and tool mentioned above, it is a common habit for the unskilled to centrally position the gage on the inverted V bearing

and move it the 6" to the right, then to the left, to spot the surface at one application. Many and varied will be the curves or "wind" which can develop from a spotting executed in this fashion. Yet judged by the uniformity of the markings, a flat surface appears to be indicated.

Another thing to be considered when spotting an inverted V is that the longer the tool, the greater the weight. As the size increases the tool becomes less responsive to muscular control. The operator is in the best position to judge when a second man is needed to guide and support, but not propel, the other end.

V's are somewhat easier to spot with a STRAIGHT EDGE than the inverted V's. It is usually possible to support the weight of the tool by resting it against one sloping side while spotting the other. By using this guide, stabilized markings are facilitated. An inverted V, on the other hand, has no comparable guide, and only the skill of the operator will ensure favorable results.

NOTE:

It might be well to remind the reader again that a long sweeping movement with a spotting tool is ill advised unless additional measures are taken to prevent "wind." See Sec. 22.8 Taut Wire Method.

Sec. 9.9
Combination Use of a Surface Plate and a Straight Edge.

On some scraping jobs, work surfaces are of such size and shape that both a SURFACE PLATE and STRAIGHT EDGE are required to spot them efficiently. For purposes of illustration we will take a rectangular surface measuring 30" in the longitudinal direction and 12" across.

In our imaginary case, assume that there are available two spotting tools neither of which is large enough to cover the entire work surface at one lay. We might have, for example, a SURFACE PLATE 16" square and a STRAIGHT EDGE measuring 36" x 2". The one is a little wider but shorter than the work piece, and the other is somewhat longer than the work but much too narrow. Though individually inadequate, they would suffice for a work piece of this size if used jointly.

These tools are applied alternately in the following manner:

The first step is to clean the work surface and then remove all burrs. Next spread a coat of marking compound, say, bluing on the SURFACE PLATE. Lay the tool on the work, approximately in the middle. Then push it to one end. Lift off, rework the compound, and replace the SURFACE PLATE at the center position of the work. Now push the tool to the other end and remove.

As an alternative method it could be pushed from one extremity to the other but on the next spotting cycle the start and finish positions should be reversed.

In either method, or variation, the important requirement is to alternate the direction of the movement. The reason for this is that a thicker film of bluing is transferred at the outset of the spotting application than at the close. Consequently, it is best to equalize the quantity of marking medium deposited over all parts of the surface, during a number of applications, by reversing the start and finish points. Used in this way, the SURFACE PLATE accurately tests the flatness of the surface in the transverse direction only.

After each application of the SURFACE PLATE, and following the scraping cycle, we should alternate with the STRAIGHT EDGE. This tool is laid parallel to the long side of the work piece. Then accompanied by a slight reciprocating action lengthwise, it is moved sidewards across the work to the opposite edge. The direction of movement from the left edge to the right edge, or vice versa, is changed each time the tool is placed on the work in order to average the amount of marking compound applied during several spotting cycles. Manipulated in this manner the STRAIGHT EDGE will accurately test the flatness of the surface in the longitudinal direction only.

Individually each tool is inadequate for spotting this type of surface, but used together they form an effective combination. By alternating them and also by reversing the direction they are pushed, a surface as accurate as the operator desires can be produced.

If the above is somewhat obscure it can perhaps be clarified this way. In pushing the SURFACE PLATE, as described, we

move it in the longitudinal direction but its accuracy of marking can be judged only transversely because it is adequate only in this dimension. In other words, the tool in question is unreliable in the longitudinal direction because it is too short lengthwise. Having this inadequacy the tool could easily dip into an imperceptible concavity or ride up a slight convexity, transversely situated, and the markings produced would falsely show a flatness on the entire surface. (See Fig. 9.2.)

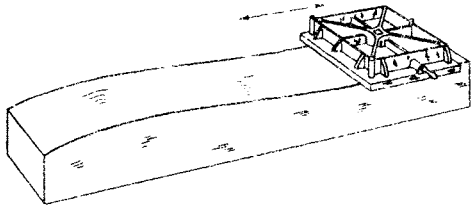


Fig. 9.2 Markings produced by a longitudinal movement of a short SURFACE PLATE on a long surface are not completely trustworthy as a convex (or concave) condition would not be detected.

In regard to the STRAIGHT EDGE, it is moved transversely but its indication is reliable only in the longitudinal direction because it has insufficient width in the cross-wise dimension. Due to this narrowness it, too, would produce misleading markings indicating flatness if either a concave or convex fault extended lengthwise on the work piece. (Refer to Fig. 9.1) Thus when used alternately in this manner, each tool tests at 90° to the other. Individually, each is accurate only in the direction which is square with the direction of movement of the tool.

We reiterate that the foregoing method, while giving reasonably accurate results, is still an expedient and that precision accuracy is possible only with perfect tools of proper size, correctly manipulated.

Sec. 9.10
Special Uses of the Straight Edge

Quick Test of a Warped Surface

It is sometimes desirable to learn if a large surface is reasonably flat and not warped, as for example, after milling or planing. A STRAIGHT EDGE is well adapted to furnish this information quickly. The procedure is as follows:

The machined surface of the work piece is first rubbed with a file to remove all the burrs and thereby avoid damaging the STRAIGHT EDGE. Next a heavy application of marking medium is spread on the face of the tool. This film will cushion the rasping effect of the still rough surface of the slab and also will transfer a readily distinguishable marking. Indications are made by placing the tool successively in the positions shown by the dotted lines in Fig. 9.3 and spotting in the usual way. The markings, if uniform throughout, will indicate a fairly flat surface. This is not a precision test used by scraping operators, but is one frequently employed by planer hands to determine the flatness of a machined surface.

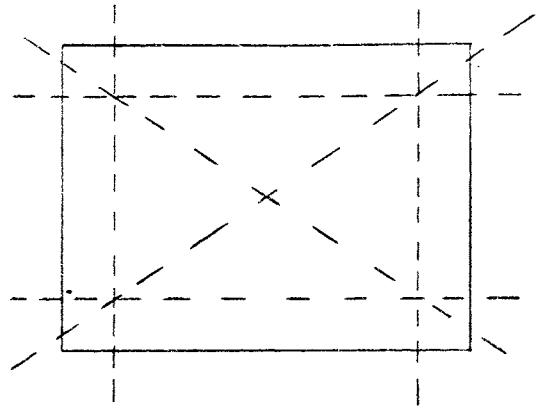


Fig. 9.3 Dotted lines show positions to lay STRAIGHT EDGE when making a quick check of a surface for flatness.

Sec. 9.11
Checking the Accuracy of a STRAIGHT EDGE

In machine shops where the various gaging tools are used by the entire personnel, damage to tools is a not infrequent occurrence. Since this damage, as a rule, is not apparent from a casual inspection, the careful scraping operator will always test before using any tool which he receives from the tool crib. This precaution will eliminate the likelihood of inflicting irreparable harm to a piece of work before a possible defect is discovered.

Some shops are equipped with a MASTER SURFACE PLATE or a MASTER STRAIGHT EDGE reserved specially for

the purpose of testing the various gages in daily use. The MASTER GAGE is never employed except to test other precision tools.

When the accuracy of a tool is in question, it may be tested by spotting it on the MASTER SURFACE PLATE. If the transferred markings are uniform, accuracy is demonstrated. When the marking is not uniform, the defective gage should be laid aside until it is repaired.

Shops which do not have a MASTER SURFACE PLATE are obliged to substitute whatever gage is at hand. Since it seems to be a common failing among many business concerns to buy only a single tool of each size, such as, one large and one small SURFACE PLATE and ditto with STRAIGHT EDGES, the net result of this false economy is all too often CONFUSION. There is no certainty that any of the gages are in accurate condition. And when a workman cannot vouch for his tools, scraping thenceforth is largely guess work.

Lacking a large MASTER PLATE, the scraper is fortunate who has available three identical STRAIGHT EDGES sufficiently long to span the work surface of any job normally undertaken by the shop. With this set he can check periodically one against the other two. Another advantage of this arrangement is that the accuracy of the smaller spotting tools in the shop, including the SURFACE PLATES, can be verified also.

Although it is by no means a quick procedure, the accuracy of a STRAIGHT EDGE can be proved without the assistance of other gages. To illustrate: With one end pointed always in the same direction, the STRAIGHT EDGE is applied to a surface for a number of spottings, which are alternated with careful scraping. As a result of these operations, the surface being scraped is developed to conform to the contour of the STRAIGHT EDGE. Naturally, the more finely the surface is scraped the greater the accuracy of the test. When the operator is satisfied with the surface he has scraped, the test is executed by spotting the test surface with the STRAIGHT EDGE turned end for end. If the markings produced on the test surface retain their uniformity of coloration and distribution, the STRAIGHT EDGE is judged accurate. Any variation whatsoever indicates that the STRAIGHT EDGE is defective.

Sec. 9.12
Checking the Accuracy of a SURFACE PLATE with a STRAIGHT EDGE.

Normally, when the accuracy of a SURFACE PLATE is suspected, the proper course is to test it with a MASTER SURFACE PLATE. As a second best choice the use of another SURFACE PLATE of equal or larger size and known accuracy is recommended. These procedures have been discussed elsewhere and are elementary. A third method which has considerable merit is to use a STRAIGHT EDGE, provided it has sufficient length to span the SURFACE PLATE in both directions. For the latter course, proceed as follows:

Deposit a film of Red Lead by evaporation over the entire SURFACE PLATE that is to be checked. (For the ultimate in precision use alcohol.) Then lay a clean STRAIGHT EDGE of proven accuracy at one end of the SURFACE PLATE and rub it back and forth several times with a longitudinal movement not exceeding one inch. Remove the STRAIGHT EDGE and clean it. Then relay it alongside the position previously occupied. Again spot the tool, remove and clean it. Repeat this cycle of operations as often as necessary, each time laying on a new place. When the SURFACE PLATE has been completely spotted the markings should be uniform over-all. If this is not the case it is not flat. For double assurance the PLATE should be spotted by the STRAIGHT EDGE in similar lays 90° to the first series.

By using a slight variation in technique, a SURFACE PLATE can be checked for accuracy with a STRAIGHT EDGE even if the latter is somewhat worn and inaccurate. Needless to say, such a practice is not to be considered standard procedure, nor is it recommended. Furthermore, the reader should not misconstrue this to mean that any old piece of iron will serve as a gage. On the contrary, the STRAIGHT EDGE must be fairly accurate so that it will spot truly over a reasonable portion of its surface. The more accurate the STRAIGHT EDGE is the fewer spottings are required, and less time is needed to analyze the SURFACE PLATE.

If this system is utilized the marking

medium is deposited as described above. Then a STRAIGHT EDGE is laid at one side of the SURFACE PLATE. Next a series of spottings is made step by step from one side of the PLATE to the other. On alternate lays, the tool is reversed. Any slight defect in the STRAIGHT EDGE will be revealed in the markings and must be in the same relative position from one lay to the next, as shown in Fig. 9.4. Thus the markings of the 1st, 3rd, 5th, etc. spottings must be identical. Similarly, the markings of the 2nd, 4th, 6th etc. spottings should also be alike. If this does not hold true, or if other non-uniformity is evident in the markings, the SURFACE PLATE is plainly inaccurate.

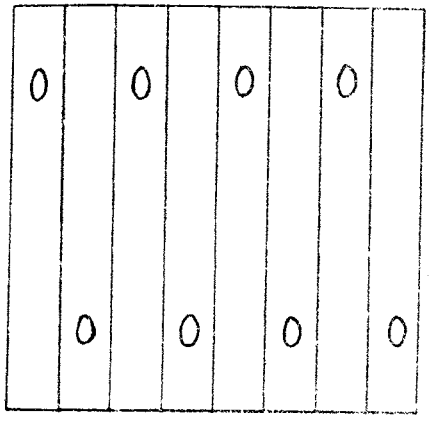


Fig. 9.4 The SURFACE PLATE tests true if the oval representing the imperfect area on a STRAIGHT EDGE maintains a uniform size and relative position on consecutive spottings.

By alternately reversing the position of the STRAIGHT EDGE and spotting it in steps all the way across the SURFACE PLATE, the condition of the latter can be judged closely with respect to flatness in one direction. Spotting the surface again, this time at 90° to the first series of markings will complete the survey.

How many spotting cycles should be conducted is left to the discretion of the operator. The certitude of accuracy in the SURFACE PLATE may well decide this.

In the test above described, small defects in the STRAIGHT EDGE can be discounted. It is the location and uniform appearance of the markings transferred to the SURFACE PLATE that indicates flatness in that member.

Sec. 9.13
The Angle Straight Edge

The ANGLE STRAIGHT EDGE is a wedge shaped spotting tool made of cast iron or steel usually cast from a pattern. It has two essential faces which are precision scraped at a certain angle to each other. (Fig. 9.5) These tools vary in size. A common length is about 3' to 4' with the width of the face between 2" and 4". Handles are provided for ease of handling.

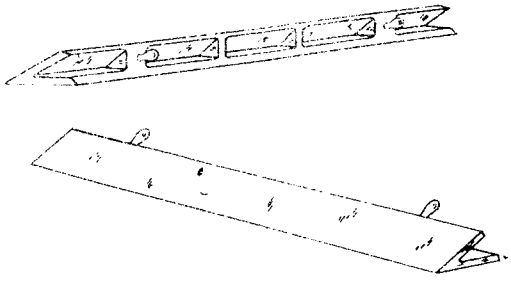


Fig. 9.5 The ANGLE STRAIGHT EDGE.

The ANGLE STRAIGHT EDGE is adaptable to any type of dovetail surface. It is particularly useful in spotting long dovetails such as are found on milling machine tables. In all such work, care in handling is mandatory because this tool is quite as subject to shock damage as the standard STRAIGHT EDGE.

When made up with the faces exactly 30°, 45° or 60° apart, to match standard dovetails, the ANGLE STRAIGHT EDGE becomes essentially a template. If necessary they can be made to any desired angle. When made in a shop doing diversified scraping, they are not held rigidly to a fixed angular standard, but are made several degrees narrower. This is done so that they will be certain to fit into all of a machine's several sets of dovetails, which sometimes vary slightly in angular value. By allowing some margin in respect to the angles, the tool is produced with less equipment and in faster time, making for economy. It is this type of non-standard ANGLE STRAIGHT EDGE that is discussed in the following paragraphs.

Sec. 9.14
Making an ANGLE STRAIGHT EDGE from a Casting.

An ANGLE STRAIGHT EDGE can be generated by the Three Plate Method or spotted on a MASTER SURFACE PLATE. The scraping process is begun after the casting has been machined to correct dimensions. Faces (A) and (B), shown in Fig. 9.6 and Fig. 9.7, are pin point hand scraped. A narrow flat is formed at the edge to prevent cutting the hands when applying marking compound.

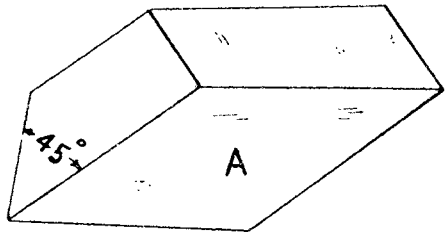


Fig. 9.6 Another type of ANGLE STRAIGHT EDGE.

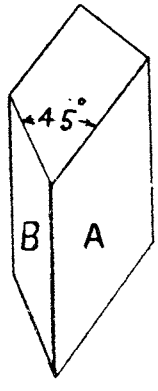


Fig. 9.7 Showing relation of scraped faces (A) and (B).

If one of these tools is being constructed to spot a standard dovetail, the two faces are scraped to a smaller included angle. This leeway is allowed so as to be certain that the tool will fit not only the dovetail in question but also other dovetails on the same machine which may vary slightly from normal.

The blunt or stub nose ANGLE STRAIGHT EDGE, represented in Fig. 9.8,

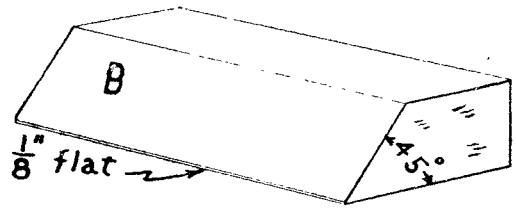


Fig. 9.8 View of blunt edge ANGLE STRAIGHT EDGE.

is the appropriate tool for use with a dovetail having wider grooves because it is less likely to bottom. Thus by filing the sharper knife-edge on a tool, it is automatically converted into a blunt edge. Obviously, the latter cannot be so easily changed into a knife-edge.

Scraping procedure to produce faces having correct angles and adequate surface bearing quality, is similar with both designs.

Sec. 9.15
Other Methods of Making an ANGLE STRAIGHT EDGE.

The production of an ANGLE STRAIGHT EDGE is both a tedious and expensive undertaking. Consequently, the scraper should know of suitable alternatives. For the occasional job requiring such a tool, it is not customary for the shop to go to the expense of having a pattern and casting made. Usually, a slab of cast iron machined and hand scraped to fit the job will suffice. This is preferable to changing the form or angle of another ANGLE STRAIGHT EDGE in the shop.

Frequently, only one face represented by (A) in Fig. 9.9 needs to be given a

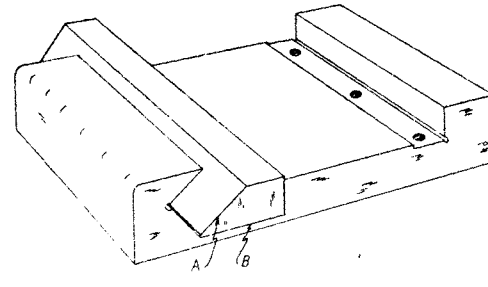


Fig. 9.9 Showing an ANGLE STRAIGHT EDGE acting in the capacity of a template while spotting a dovetail.

surface plate quality, the other face (B) merely being scraped flat. When this is done, the pin pointed surface acts as the spotting tool and the less finished face merely serves as a guide against a flat bearing.

To save additional time, one face may be scrape-finished while the other face is left as it comes from the milling machine or planer. If this expedient is resorted to the spotting can be effectively performed by manipulating the scraped face in contact with the side of the dovetail, as represented in Fig. 9.10.

NOTE:

Stabilized markings are promoted by allowing the groove to support the weight of the tool.

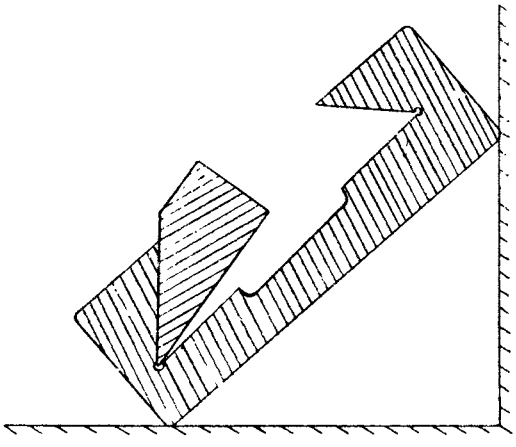


Fig. 9.10 Showing ANGLE STRAIGHT EDGE supported by groove.

Sec. 9.16
Reconditioning the ANGLE STRAIGHT EDGE

Since use and abuse take their toll, precision gages must be rescraped from time to time in order to maintain them at highest efficiency. This task is often undertaken by the mechanics in the shop. Ordinarily, it is not a difficult operation, since usually the work is attempted before the tool is too badly worn. However, because it does appear to be easy, the job is sometimes botched, and all because of one small but distressing oversight.

In rescraping a worn ANGLE STRAIGHT EDGE the salient point to remember is that the border area, lying near the knife-edge must be just as flat and true as the center portion. The reason for this is apparent from a study of a few horrible examples, as shown in the accompanying figures.

It will be seen that the ANGLE STRAIGHT EDGE shown in Fig. 9.11 will not spot accurately when inserted into a

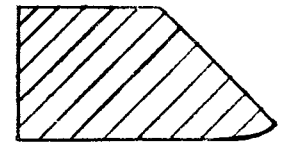


Fig. 9.11 View of ANGLE STRAIGHT EDGE imperfectly scraped near knife edge.

dovetail. The reason is that one of the spotting faces of the tool is not perfectly flat and true, instead it is curved. If a machined surface is spotted by such a tool, and the scraping is conducted in accordance with the markings thus transferred, the curve is reproduced on the bearing surface, as shown in Fig. 9.12. The drawing necessarily exaggerates the curvature of the bearing surface but nonetheless suggests the difficulty of securing a true plane under such conditions.

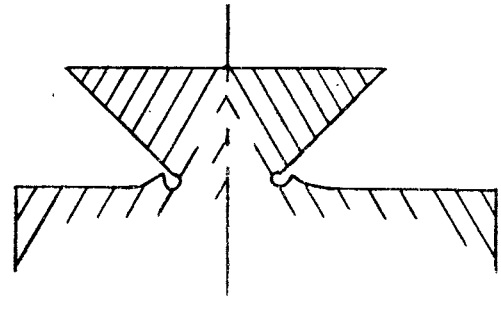


Fig. 9.12 Showing effect on bearing surface of stationary member as a result of spotting with an imperfect tool.

A secondary effect of poorly scraped testing gages is seen when the female dovetail is fitted onto the male dovetail, as shown in Fig. 9.13. It will be noted that the upper member rides the curvature and that excessive wear, or even scoring,

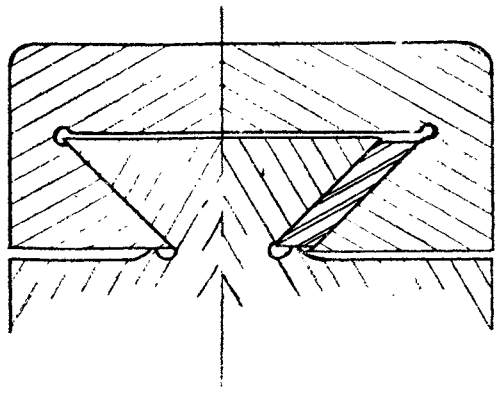


Fig. 9.13 Showing line contact resulting as sliding member is mounted on a stationary member made defective by improper spotting.

inevitably occurs at these locations. The gib piece, also shown in Fig. 9.13, is similarly affected. The result is that the mateing member will be prematurely thrown out of alignment. This may necessitate the complete overhaul, of not just the one member concerned, but possibly other members dependent on it. Thus the work snowballs, as one surface after another requires rescraping to adjust it to new and correct positions.

Q. When rescraping a worn ANGLE STRAIGHT EDGE is any special procedure used?

A. The necessity of scraping the faces of the tool flat and true right up to the knife-edge has been discussed above. Except for that precaution, it can be treated like any other small, flat work piece. However, it must be spotted on a MASTER SURFACE PLATE as a guarantee of accuracy. Lastly, the operation cannot be concluded until a SURFACE PLATE bearing quality is achieved on one, or both faces, as required.

Sec. 9.17
Spotting a Dovetail with an ANGLE STRAIGHT EDGE

The correct method of applying marking compound to a dovetail with an ANGLE STRAIGHT EDGE is by grasping the end of the tool with one hand. This hand pushes and pulls the tool a few inches each way. Meanwhile, the other hand supports the weight and serves to guide and steady the gage in contact with the angular side of the dovetail, as shown in Fig. 9.14.

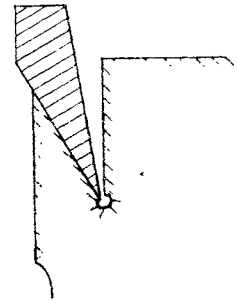


Fig. 9.14 Demonstrating method of spotting a dovetail by holding ANGLE STRAIGHT EDGE against inclined surface.

This is a difficult feat to perform, considering the weight of the tool and its tendency to slide down against the flat way.

An alternative system can be employed if the groove is sufficiently large to accomodate the ANGLE STRAIGHT EDGE without bottoming. In this method the tool is allowed to slip down as far as it will, with the knife-edge entering the groove. (See Fig. 9.15) The arrangement shown allows

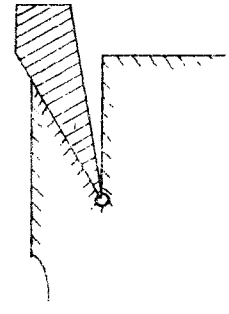


Fig. 9.15 Alternative method of spotting a dovetail by allowing ANGLE STRAIGHT EDGE to slide down into groove for support

the flat way to bear part of the weight of the tool at the point where the groove makes a juncture with the dovetail. However, it must not bottom in the groove. Thus with the sides of the groove supporting the weight, the tool can be tilted by hand against the surface to spot it. The hand regulates the spotting pressure.

Stabilized spotting conditions and true markings are consistently produced with this technique because the tool assumes the same position each time it is inserted.

Sec. 9.18
Improper Method of Holding the ANGLE STRAIGHT EDGE Against a Dovetail.

Never place one hand at each end of the ANGLE STRAIGHT EDGE and press it against the dovetail. This practice will bow the tool if it is slender. Even if the tool is substantial enough to resist the pressure, the method will nevertheless, lead to errors in the markings. Invariably the end result is the development of a convexity on the dovetail surface.

Chapter 10

MARKING MEDIUMS

Any solid, semi-solid, or fluid employed for spotting is termed a marking medium. There is a considerable diversity of opinion among machinists as to which of the substances commonly used is best for this purpose. The selection of compound must be made upon the basis of the conditions of use. That is, each type is perhaps best suited to a particular class of work, although two or more kinds may perform equally well on certain jobs. Some operators, from force of habit, employ only one marking compound regardless of the character of the work. But it is frequently advantageous to vary the medium or even to apply two kinds on the same surface to obtain contrasting colors for greater visibility. A discussion of this technique is reserved for a later paragraph.

The various marking media are bracketed under the general heading of Marking Compound, or, simply compound, although sometimes the terms, transfer medium, paste, bluing etc., are used interchangeably. This inclusive term embraces Commercial Bluing, Prussian Blue, Red Lead; various solvents, such as alcohol, benzine etc.; also the powdered pigments, Lamp Black, Indian Red etc. It further denotes all the diverse shades and mixtures of these materials. It will be left to the reader's initiative to try them all, and select the one best suited to his class of work.

Sec. 10.1
Bluing

Bluing is a general term rather loosely employed in the scraping art to identify a marking compound, or a spotting paste having an oil base. Included in this category are Prussian Blue and various commercial makes of paste.

It is the function of "bluing" to indicate the irregularities on a work surface. This is accomplished by spreading the bluing in a thin film on the face of a tool, such as a SURFACE PLATE or STRAIGHT EDGE. When the tool is rubbed on the work, some of the bluing transfers from the tool to the high spots on the surface. In this way the high spots are made visible.

Sec. 10.2
Prussian Blue

Prussian Blue is a concentrated oil paint used in coloring by artists. It may be purchased at most stores selling artist's supplies. This substance leaves clear, sharp and distinct markings and in these characteristics it has no peer among the bluings. For this one reason, many operators are willing to put up with its several disadvantages, especially when engaged on precision work.

The disadvantages inherent in Prussian Blue are as follows:

1. It is difficult to spread quickly and uniformly on the spotting tool because it is both viscid and adhesive.
2. It has a tendency to dry out in a short time when applied thinly. However, little or no difficulty is experienced on average jobs when the time interval between scraping cycles is brief. For speeding the distribution of Prussian Blue, a solvent is very helpful. A few drops of benzine also improves the consistency of the compound when reworking a film on a surface.
3. The Prussian Blue must be completely removed from the tools and the work surface after each day's work. If this is not done the tool will be caked and unserviceable until it has been cleaned. The cleansing may be done with any solvent.

Sec. 10.3
Commercial Bluings

There are on the market a number of trade marked commercial bluings, known by the general term of "bearing bluing." In producing these spotting pastes, several manufacturers combine Prussian Blue with oil, others utilize special formulas. In tinctorial power, some of these products closely match the intense blue coloring of Prussian Blue. Furthermore, having been developed specifically for the scraping art, they possess a number of additional advantages. Their most notable improvement has been the elimination of the objectionable tendency to dry out. The better commercial bluings will neither skin nor dry out, even if spread very thin. They can be left on the tools or work surface over night, or for several weeks duration, if need be. The film remains wet and transferable throughout this period. Thus considerable labor and time is saved in cleaning up and spreading fresh coats. Commercial bluings are also very soft and smooth, without grit, and are non-injurious to metal.

Sec. 10.4
Inferior Commercial Bluings

There are offered for sale a few commercial bluings whose chief claim seems to be that they won't dry out. While this claim is undoubtedly true, these substances are, nonetheless, worthless for scraping purposes. The reason is that, having scarcely any coloring, they are practically invisible when spread thin. Common lard could hardly be less effective.

Under heavy pressure, which naturally produces heat, some types of bluing will run like oil and spread all over the bearing surface. This characteristic makes it very difficult, if not impossible, to determine the high spots. This condition is most frequently observed when employing, as a spotting template, a machine member having considerable weight.

The scraping operator will have to learn by trial and error which brand, or make, of commercial bluing is most satisfactory to him.

Sec. 10.5
Applying Bluing to the Tool

When applying the bluing, press the tube and keep a slow and steady flow coming. Dot the SURFACE PLATE, or other spotting tool, at spaced intervals over its entire surface. Experience will show how copious each dot should be and how many are required. Speaking generally, the more worn and rough the work surface, the more compound will be initially needed for the job. NEVER squeeze a stream of bluing out of the tube into a pool in the middle of the SURFACE PLATE because it is then difficult to judge the quantity.

After enough bluing has been dotted over the SURFACE PLATE it should be spread with the fingers and palm of the hand until it covers the entire surface (or that portion to be used). Apply an even coat, rubbing from several directions. Continue until there are no streaks of thick, unworked, unspread material. This condition is indicated by a uniform coloration overall. It is judged entirely by eye. A single coating of bluing on the spotting tool is usually enough for one average job, because the medium can be easily reworked.

Commercial bluings with an oil base are more readily applied than Prussian Blue, and no difficulty is experienced in obtaining a uniform coating. Should it be desired to thin the compound, the application of a few drops of a volatile liquid, such as benzine, will accomplish this.

Some operators apply bluing with a cloth or felt pad but this method is not as safe as application by the hand. The reasons are not difficult to find. In the first place, the bare hand is highly sensitive in detecting damaging grit or foreign particles on the tool. Another reason is the fact that lint ravels off the cloth and adheres to the bluing on the SURFACE PLATE. This happens occasionally and is something to be guarded against because it would affect the accuracy of the markings.

Sec. 10.6
Reworking the Bluing on the Tool

After the bluing is spread over the SURFACE PLATE, as evenly and as thinly

as required, the tool is rubbed on the work surface. This spotting procedure removes a portion of the bluing from the face of the tool. Before the tool can again be used with accuracy, the compound must be replaced. Usually there is on adjacent areas of the tool sufficient excess to distribute over the bare places. Obviously, as this process is continued, the quantity available for this purpose is progressively reduced. This trend, however, proves to be very advantageous because, as the surface is scraped smoother, proportionately less bluing is needed to obtain accurate markings. It is an axiom of the scraping art that the thinnest possible film of marking compound, consistent with full coverage, increases the accuracy of the markings.

This act of brushing, or rubbing out, the bare places with the hand, is known as reworking. Needless to say, this process can be carried just so far, and then extra compound must be added, if needed.

Sec. 10.7
Cleaning off the Bluing

Cleaning the surface of the work piece after each and every scraping cycle, is one of the more humdrum tasks performed by the scraper. While this is a common chore, it is nonetheless an important one. During the process of scraping a residue of metal particles and bluing is strewn over the surface of the work piece. The loose debris can be removed with a brush or cloth. Then the burr file is applied over the entire scraped area, to smooth the roughness. Any metal particles resulting from this operation are whisked away. See Sec. 3.6 on Burrs. Next the sensitive bare hand is rubbed across the surface to detect and remove any stray pieces of grit. All this must be repeated after each and every scraping cycle, before again applying the spotting tool to the work surface. This routine cannot be shirked without inviting damage to the tool, as well as risking inaccurate markings.

The directions specifying a thorough cleaning of the surface of the work piece with the bare hand, before again applying the tool for spotting, run counter to fundamental shop methods governing the machining of metal. Since the foregoing is recommended as standard practice in scraping operations, it might be well to explain the seeming discrepancy.

It is the common rule in the machine shop to avoid touching a piece of cast iron with the fingers or hand just before taking the final machining cut. Any oil smudged on will cause the cutting tool to skid across this particular area of the work surface leaving an imperfection in the finish.

Different conditions apply, however, in scraping operations. Here it is essential to explore carefully the work surface with the bare hand, to detect the presence of burrs, grit and all foreign matter. The palm of the hand is also ideal for the removal of loose contaminations.

Sec. 10.8
Applying Bluing to the Work Surface

Sometimes operators, at variance to the usual practice of coating the tool, spread a thin film of bluing over the entire surface of the work piece. The high spots are then located by applying a clean SURFACE PLATE or STRAIGHT EDGE to the coated surface. Where the spotting tool touches on the high spots, the bluing is, more or less, rubbed off. The operator then scrapes these colorless, or off-colored areas. While the spotting tool may not remove all the bluing from the high spots, it will remove some. This decreases the thickness of the original, uniformly blue film and modifies the coloration. Thus to an experienced operator, the change in shading of the color will differentiate the various heights of the irregularities.

The disadvantage of this system of spotting is that, after each cycle of scraping, metal particles will be intermingled with the film of compound on the work surface. Therefore, all of the bluing must be cleaned off the entire work piece before the burrs can be removed and a new coating of compound applied. The considerable time required to remove the bluing causes this method to compare unfavorably, from the standpoint of speed, with the ordinary method of spreading bluing on the tool.

The principal advantage of the practice is the improved visibility of the high spots which stand out vividly against the blue

background. Although operations are slower, this technique is favored by some experienced operators when illumination is inadequate.

Sec. 10.9
Spreading Marking Compound: Choice of Surfaces

As we have pointed out above, it is standard practice to apply marking compound either to the spotting tool or to the work surface, but there is nothing haphazard about this. Knowing when one method of application is more appropriate than the other is important, as proper selection improves accuracy and efficiency. In addition to the suggestions on this subject given above, the following pointers will assist the apprentice in choosing procedures most suitable to any given case.

The size of the available tool in relation to the work surface influences the decision as to where the marking compound is to be applied. For instance, when the spotting tool and the work surface are equal in size, or nearly so, ideal conditions prevail and the marking medium can be spread on either without noticeable advantage.

When the tool, say a STRAIGHT EDGE, is longer in one dimension, though narrower in the other dimension than the work surface, the practice of spreading compound on the work surface has considerable merit. However, each situation must be studied individually. Having a uniform film on the work surface, the STRAIGHT EDGE will indicate the high spots with maximum accuracy. In contrast, when the marking compound is spread on the tool, a non-uniform application is inevitable because more compound is transferred at the start of the sidewise movement than at the finish. In other words, the maximum quantity is on the tool to start with and the amount available is gradually reduced by the longitudinal rubbing movement as the tool is pushed sidewards from one end of the work surface to the other. The result of this is that the high spots, at that side of the work piece which was spotted first, will appear more prominent than those high spots on adjacent portions which were spotted next, and so on progressively. This condition can lead to serious mistakes when analyzing the markings as they must be judged entirely by eye on the basis of their coloration.

On the other hand, if the work piece is larger than the tool in both directions, the marking compound should be spread on the tool, not on the work. The latter course would lead only to confusion in interpreting the markings. The reason for this statement is that on account of the inadequate size of the tool, it would be necessary to lay it two or more times on some portions of the work piece in the process of spotting the entire area. Obviously, if this were done, the markings would be distorted, even obliterated, in those places where the spottings overlapped.

To demonstrate this, assume that we are utilizing a STRAIGHT EDGE that is both shorter and narrower than our imaginary work surface. If accurate markings are to be obtained the medium should be applied only to the tool. The procedure would involve spotting the work surface in orderly steps a portion at a time. This problem of applying a STRAIGHT EDGE to a work surface that is much larger than itself, has been described at length in Sec. 9.7 and it would be repetitious to explain again. However, we will mention once more that an important feature in the success of such a spotting technique is a Markings Chart. (Sec. 11.8)

Another factor to be weighed, before deciding whether to coat the tool or the work surface, is the relative smoothness of the latter. For example, when starting to scrape a rough surface, the marking compound should be applied to the tool. This is advisable because the compound will be transferred to only a few very high spots on the work surface. When these are removed with the scraping tool it is an easy matter to brush off the debris from the clean, dry work surface. This would not be possible if the work piece has been coated. Only careful cleaning of the entire area could then prepare it for another spotting cycle.

On the other hand, when the work surface is nearing completion and is showing a fine finish, there are advantages in proceeding differently. It is often advisable to coat the work piece with marking

compound during the late stages of a job because then the scraping strokes are usually directed quite generally over the entire work surface. Consequently, the aforementioned objection to grit littering the surface is no longer a valid one since the surface must be cleaned in its entirety anyway.

In cases where illumination is substandard, or when improved visibility is desirable for very particular jobs, the compound should be spread on the work surface providing the spotting tool is the appropriate size.

Sec. 10.10
Quantity of Bluing

Under most conditions, the minimum of bluing is applied to the tool because experience shows that a thin film renders more accurate results. The reason for this is that the curvature (convex or concave) on the work surface will be cushioned, and to a degree, concealed by a thick coating of compound. Moreover, with a thick coating of marking medium the quantity stripped off the tool by the rubbing movement would tend to exaggerate the size of the high spots and give poor definition. Therefore, to increase the probability of accuracy when scraping a surface flat, the thinnest film of compound should be spread during the final cycles. On jobs requiring the highest precision, the selection of the medium should be made with discrimination. That is, a type depositing the thinnest practicable film is chosen.

On the other hand, when the operator is confronted with a very rough surface, the application of a liberal amount of compound will actually expedite the work. Until the surface has been made fairly smooth, accuracy of markings is of secondary importance and speed, obviously, is paramount.

In scraping extremely rough surfaces, we are concerned not so much with individual high spots as with extensive high areas. The latter require marking compound in generous quantities to show up vividly. Consequently, there should be sufficient bluing available to transfer readily from the spotting tool to the work surface.

Another reason why a thick coat is desirable at such times is to lubricate or cushion the tool from the rasping effects of the roughnesses and irregularities of the work piece.

Sec. 10.11
Interpreting the Markings when Using Bluing

Knowing where to scrape and how deeply to shave off the metal is fundamental if scraping is to be conducted with efficiency and accuracy. This calls for unerring identification of the high spots. The operator must realize that high spots are revealed by the medium only after being acted on by a tool of known flatness. Whether the medium is spread on the work surface or coated on the tool is immaterial. It is the rubbing action and the pressure between the work surface and the tool that causes the roughnesses to assume an appearance different than adjacent portions of the same surface.

Thus if we apply a coat of bluing compound to the entire work surface it will be the variations from the uniform overall coloration that will be the criterion of surface irregularity. Areas coated with the natural color of the marking substance indicate that the underlying surface may be flat or even concave. These portions should not be scraped. If the bluing is a lighter color, it signifies that a slight pressure was imposed on that particular place. Scraping here should be delicately performed and may even safely be postponed until a following cycle if other areas show signs of heavier pressure, such as off-color or brownish markings. Both of these are indicative of prominent high spots and should be dealt with first. Off-colored markings signify that most if not all of the medium has been stripped away by the rubbing action of the tool. The brownish markings indicate that there has been actual metal to metal contact between the tool and the work piece.

As the work piece is scraped flatter the coloration of the markings becomes progressively more uniform. This condition necessitates the most exacting attention on the part of the scraper. Needless to say, keen vision and color perception are requisite if the markings are to be correctly interpreted.

When the markings are uniform in color

and evenly distributed, and additional spotting and scraping cycles do not show perceptible improvement, either in coloration or placement, the work surface is considered scrape-finished. Of course, by changing the medium to Red Lead deposited by evaporation, or better yet, alcohol, further refinement could be made. For work demanding the highest precision this would, no doubt, be done. These techniques are discussed in a later paragraph.

Sec. 10.12
Red Lead or Minium

Red Lead is a heavy powder of a beautiful red color much favored by scrapers. The fineness of the particles is an important reason for its popularity as a marking medium. Its cheapness is also a factor which recommends its usage.

Procured in powder form, in a very uniform range of particle size, Red Lead when mixed with oil makes an efficient marking medium. To prepare it, a quantity of the powder is placed in a container and machine oil is added. Being in fine powdery form it does not mix readily with the oil and considerable pounding and kneading is required to unite them. When the preparation has reached the consistency of shoe polish it is placed in a convenient package, such as a snuff box, and is ready for use. Since the Red Lead compound improves with ageing, it is better after one year of storage than the day it was made. The reason for the improvement is that the oil dries out and the compound becomes caked. In this condition it is most conveniently applied to the work surface or to the spotting tool, as will be described.

There are two practical methods of applying Red Lead. One is known as "depositing by evaporation" and is suitable for work surfaces. In this application the Red Lead serves simultaneously as a background and as a marking medium. In the other method, the Red Lead is applied with oil to the spotting tool and used like any other oil base marking medium. A complete explanation of both applications is made in a later paragraph.

Incidentally, Red Lead being capable of absorbing large quantities of oil doesn't flow as readily under pressure as bluing. In circumstances when more accurate markings are desired, this proves to be a decided advantage.

Sec. 10.13
Red Lead Mixture

One of the techniques employed by the experienced operator to secure the advantages of improved visibility is the application of a contrasting color to the work surface via his spotting tool. To provide this contrast, it is possible to alter the color of the basic Red Lead. This is done in several ways, and the result of the operation is known as Red Lead Mixture.

Indian Red when added to Red Lead will produce a richer, deeper red. The addition of Prussian Blue will turn it to a dark olive drab. Lamp black can be added to produce a range of browns from light copper to a very dark brown.

The addition of these pigments will not appreciably affect the spotting quality of the compound since their particle size closely approximates Red Lead. The mixture is prepared in the same way as the unadulterated Red Lead, namely, by adding machine oil. It should be stored in the ever-handy snuff box for future use.

Ability to prepare various shades, tints and hues of Red Lead Mixture, by mixing a pigment with the Red Lead, proves useful when different colored metals are scraped. By compounding the appropriate mixture the operator provides himself with a marking medium having the greatest possible visual contrast between the work surface and the high spots.

As with unadulterated Red Lead, the Red Lead Mixture is applied either to a work surface by "depositing by evaporation", or spread on the tool with oil.

Sec. 10.14
Comparing Red Lead and Red Lead Mixture

There should be no confusion between Red Lead and Red Lead Mixture, despite the similarity of the terms. Both are marking mediums; both may be deposited by evaporation on the work surface; and both may be spread with oil on the spotting tool. The particular selection of one or the other depends on the situation.

For example;

1. Either substance may be deposited by evaporation on the work surface to provide a contrasting background for a different colored compound applied by the tool. This procedure is frequently adopted for the average scraping job.
2. Similarly, either substance may be deposited on the work surface, as mentioned above, and then marked by applying a clean dry tool. This procedure is suitable for precision jobs.
3. Finally, either substance may be spread on the tool, using oil. This practice is followed on ordinary jobs, whether the work surface is coated with a contrasting film deposited by evaporation, or is covered with a marking medium having oil as a base. When they are used simultaneously, Red Lead, having the smallest and most uniform particle size is deposited on the work by evaporation only. Then for maximum contrast, Red Lead Mixture is spread on the spotting tool, using oil.

The technique of performing each of these operations will be described separately. Then the complete spotting cycle will be discussed.

Sec. 10.15
Depositing Red Lead by Evaporation

The technique which consists of depositing Red Lead (or Red Lead Mixture) on the work surface; removing the excess by lightly wiping with a cloth; and retaining a thin film, which drys on the surface, is known as "depositing by evaporation." The evaporation method for producing thin films is simple in its mechanism and in its practical application. Details of this procedure are as follows:

A piece of felt, two or three inches square and about 1/2" thick, is moistened with alcohol, naptha or benzine, and rubbed once or twice across the Red Lead in the container.

(This initial application of the solvent will last for several cycles. When the felt is too dry, more liquid is added. A pint size bottle makes a convenient container for the fluid.)

The Red Lead clings to the felt which then is applied to the work surface. Being thus mixed with a volatile fluid, it spreads easily and flows into all the tiny scratches made by the scraper blade.

To ensure a uniform coating, a cloth is wiped across the work surface a few times to remove the surplus. The remainder drys quickly to a uniformly thin, powdery film of light reddish orange color. Once dry, this coating should not be touched with the fingers as it brushes off easily. The work surface is now in a condition to be spotted with the tool.

The process of scraping away the high spots indicated by the spotting operation necessarily removes part of the film of Red Lead. Fresh coats, therefore, are applied in the same manner following each scraping cycle.

The critical reader has no doubt noticed that we suggest using a felt pad to spread the Red Lead and a cloth to wipe off any excess. This is at odds with the recommendations for applying bluing, wherein the danger of lint or shreds raveling from the felt or cloth was stressed. However, in the present case, there is no other practical method of application so the risk of lint falling must be chanced. Fortunately, this is not very likely since the powder gathered on the pad is in a solution and spreads easily. Furthermore, no prolonged rubbing is required to distribute a uniform film as is necessary with bluing. Objections to the employment of a wiping cloth can be similarly dismissed because the cloth is only lightly brushed along the work surface and little if any fraying occurs.

Red Lead (Red Lead Mixture) is applied to the spotting tool with oil as follows:

Sec. 10.16
Application with the Fingers

Moisten the finger tips of one hand with a drop or two of oil. Then brush the finger tips of both hands briskly together to spread the oil uniformly. Next gather a quantity of compound from the container by wiping the oiled fingers across the compound and apply it evenly over the tool. The advantage of using the fingers is that any stray particle of grit can be detected and removed while applying the compound. After the first spotting cycle

the compound on the tool may be reworked. This operation likewise consists of rubbing the oiled fingers over the entire surface of the tool which spreads the medium evenly and, of course, somewhat more thinly.

Sec. 10.17
Application with a Dauber

Since the operation is speeded up considerably by spreading with a cloth or felt pad and smoothing with a brush, many scrapers prefer this method in spite of the attendant hazards. When the compound is applied in this way, moisten the dauber with a few drops of oil. Gather a quantity of compound and spread it across the tool. Distribute it more evenly with two or three quick swipes of a dust-pan type brush. Then after the first spotting cycle it may be reworked, provided there is sufficient compound remaining on the tool face. Reworking consists of whisking the brush back and forth a few times giving a uniform spread. Ordinarily, the bristles become sufficiently saturated after a few cycles to obviate the need for additional oil.

This practice, in spite of its speed, is not without its disadvantage. There is a serious danger that in using the brush a stray particle of grit clinging to the bristles may be deposited on the tool face. Since the face would not be explored for such foreign matter A F T E R spreading the compound, it would go undiscovered. A score on the tool, or on the work, would be first indication of its presence.

To avoid such misfortune take all precautions to prevent contaminating the brush with grit or chips. Never use the same brush for spreading the compound and also for sweeping away the cuttings.

Sec. 10.18
Red Lead and Red Lead Mixture in the Spotting Cycle

Assuming both the work surface and the spotting tool have been prepared, we will now bring them together and complete the cycle.

The spotting tool is laid on the work, rubbed a few times and removed. Before any scraping is attempted, the markings must be correctly interpreted. This subject is discussed in the very next section but first we will conclude the mechanical routine. Now to continue: After the markings are analyzed, the indicated high spots are scraped. The metal particles are brushed off; burrs are removed; and the grit is swept away. Then another coating of Red Lead is deposited by evaporation on the work surface. Meanwhile the Red Lead Mixture on the tool surface is reworked with the oil moistened fingers. Now that the tool is ready to spot the work surface again, the cycle is complete. This sequence of operation is repeated until the requisite flatness, alignment, and surface bearing quality are achieved.

Incidentally, the chief reason why oil must be used to rework the Mixture is that at each spotting, the film of Red Lead evaporated on the work surface absorbs much of the oil from the Mixture coating the tool. The Red Lead deposited by evaporation on the work surface has a powerful drying action on the oil mingled with the Mixture. Therefore, unless oil is added when the Mixture is reworked it soon becomes dry and crumbly and will not spread.

Sec. 10.19
Interpreting the Markings when Using Red Lead

When working with a Red Lead Mixture coating on the tool, and a film of Red Lead deposited by evaporation on the work piece, the operator judges the relative height of the various irregularities by their coloration. This combination of substances has the property to register a considerable range of surface inequalities by the difference in color. The shadings vary according to the pressure applied to the high spots by the weight of the spotting tool. The highest points, which bear the maximum load, are denoted by a polished black mark. The next highest are indicated by shades of brown. Where the natural color of the Red Lead Mixture is seen, very little pressure has been applied. (The high spots obviously, are located where the Mixture overlays the Red Lead.) The balance of the work surface, which was not smeared by contact with the tool, retains the original distinctive

coating of Red Lead.

When black marks are in evidence these highest spots are given priority for scraping. As the surface becomes smoother, the black disappears and the coloration of the markings becomes more uniform. This condition necessitates careful judgment as to where and how much to scrape to make the surface progressively flatter.

Having explained the proper spotting procedure for average jobs of work, we will now describe briefly certain practices that make for more efficient use of these materials.

Sec. 10.20
Re-working the Red Lead Mixture on the Tool

After the first spotting cycle the remnants of the initial application of the Red Lead Mixture must be re-worked. This is done by moistening the fingers with oil and thoroughly rubbing the entire surface of the tool. It is the only way to prevent the Mixture from becoming crumbly. As each successive spotting transfers more of the Mixture to the work surface, the residue on the tool is gradually diluted with oil. Eventually, the amount of compound on the tool becomes, for all practical purposes, non-existent. Thenceforth, spotting is possible only because oil from the tool acts on the Red Lead deposited by evaporation on the work surface. This transition occurs during the final stages on the average job. The accuracy of the marking is high if the quantity of oil is kept to a minimum. As before variations in coloring indicate the relative height of the high spots.

Sec. 10.21
Initial Application of Red Lead

One peculiarity the operator will discover when depositing Red Lead by evaporation is that it does not adhere very well to bearing surfaces that are slick from wear and thoroughly saturated with oil. Such a condition is encountered when commencing to rescrape the slides and ways of worn machine tools. After the first few scraping cycles, the Red Lead begins to cling more evenly, and no further difficulty on this score is experienced.

Sec. 10.22
Hints to Improve Technique

1. After some use the wiping cloth becomes soiled and a trifle oily. This is a desirable condition because it is then possible to remove the Red Lead more sparingly. It helps retain just the right film density on the work surface.
2. In the process of depositing Red Lead by evaporation the first and subsequent deposits may be made thicker or thinner, merely by varying the quantity of volatile fluid on the felt pad. Increasing the quantity of the solution has the effect of decreasing the thickness of the deposit of compound, and vice versa. The compound can be spread as thin as desired and very uniformly. This characteristic is of great importance especially when the work is in the critical finishing stages.
3. After the light film deposited on the work surface has dried, avoid touching it with the fingers or these areas will not show up so well when spotted by the tool.
4. The condition of the work surface is the principal factor in determining the required thickness of the Red Lead compound deposited by evaporation. The actual quantity deposited is regulated by the solvent.

Sec. 10.23
Red Lead for Precision Work

Red Lead is also suitable for high quality jobs, such as reconditioning SURFACE PLATES. On precision work of this nature, the work surface is coated by depositing Red Lead by evaporation. The excess is removed with a cloth. The fingers, as we have said repeatedly, are never touched to the thin film that remains because such places will not mark when spotted with the tool. This much is standard practice for all types of work. The variation occurs in the preparation of the spotting tool.

For precision work the spotting tool is treated differently than when readied for ordinary jobs. In the first place a clean tool is used. That is, no oil is applied to it, except what may by coincidence happen to be on the operator's hands when he wipes the tool to detect grit. In other

words, the tool applied to the work surface spots dry. The weight of the tool will form highly polished blackish marks which are prominent against the reddish orange work surface. Their high visibility makes it a comparatively easy matter to pin point them.

Sec. 10.24
Red Lead Contrasting with Red Lead Mixture

As mentioned before, Red Lead is sometimes deposited on the work surface and there used as a background against which a Red Lead Mixture spots more vividly. The method of applying either of these compounds separately to the work surface and to the tool, has previously been adequately explained. A few paragraphs may now be necessary to correlate the use of the two compounds when they are used together on work surfaces of varying grades of smoothness. For instance:

1. During the initial and intermediate scraping cycles when the work surface is still quite rough, use ample quantities of Red Lead Mixture and apply it to the tool with oil. Taper off the amount of mixture as the scraping proceeds, adding a fresh batch only if needed.
2. As the work surface nears completion and acquires a good finish, apply only oil to the spotting tool as a marking medium. This will mark the Red Lead which has already been deposited by evaporation on the work surface.
3. For those occasional jobs when work of the highest precision, such as reconditioning SURFACE PLATES or STRAIGHT EDGES etc., is called for, keep the spotting tool clean and dry. Use neither compound nor oil. The marks will be formed by pressure of the tool rubbing on the thin film of deposited Red Lead covering the work surface.

Sec. 10.25
Incidental Uses of Red Lead

Red Lead may often be used to advantage in conjunction with bluing. The Red Lead is deposited by evaporation on the work surface and the tool is coated with bluing. After the tool is applied to the work, the high spots are very prominent as blue marks against the reddish orange background of the work. Under conditions of poor lighting this method is very effective.

Sometimes a quantity of Red Lead and kerosene are mixed together and applied with a dauber to the work surface. It is worked well into the tiny scratches and remains there as a background. Bluing applied to a spotting tool and transferred to the Red Lead background will provide a vivid contrast. The Red Lead remains caked in the tiny scratches until removed by scraping which usually will be several cycles later.

Sec. 10.26
Lamp Black or Carbon Black

Lamp black is a soot, jet black in color, obtained by burning bodies rich in carbon in an inadequate supply of air. In the metal trades it is used by some mechanics as a marking medium. Its intense blackness shows up well especially against a light background, such as provided by the lighter colored metals, aluminum, tin, copper, brass etc. On cast iron or steel surfaces, lamp black, when applied in a very fine film, does not have the staining quality possessed by Prussian Blue.

Its cheapness, especially where large quantities are involved, is a point in its favor. More important, however, is the fact that the composition of the substance can be varied to meet individual requirements and made up by the mechanic, as needed.

To mix lamp black so that it is suitable for spotting purposes is not unusually difficult. A quantity of the material is placed in a container. Oil is slowly added to the contents meantime stirring vigorously. The lamp black does not combine readily with the oil and prolonged kneading of the ingredients is necessary. When the mixture has reached the consistency of shoe polish it is ready for use.

Lamp black is applied in the same way as the commercial bluings. It is readily cleaned off the work surface and tools by the usual methods.

Sec. 10.27
Alcohol

When a surface requires extreme accuracy, the marking medium usually employed to indicate the irregularities is alcohol. It is used principally in the final pin pointing of precision tools, such as, SURFACE PLATES, STRAIGHT EDGES etc.

Application of the alcohol is with the hand. A small quantity of the fluid is poured onto the work surface and then spread over and around with the bare hand, till the entire area has been covered. The liquid evaporates very quickly leaving a dull film. After the clean spotting tool is rubbed on the work surface, the presence of all high spots is indicated by a bright shiny mark against the dull background.

The greatest care is necessary in working with this alcohol residue. It is not a lubricant and therefore the rubbing movement should be the very minimum needed to produce the bright marks. An excessive movement may cause the face of the tool to be scored by the high spots on the work surface.

Sec. 10.28
Indian Red or Persian Red

This earthy substance was originally brought from the Persian Gulf, hence the name. It is a dark, purplish red earth, or pigment, occurring naturally. It is also made artificially. A very fine variety is used in scraping operations to vary the shade of other marking compounds. When added to Red Lead it produces a richer, deeper red, that is valuable for contrasting effects.

Sec. 10.29
Venetian Red

Venetian Red is an earthy variety of hematite (ferric oxide). It is also produced artificially. In color it is a brilliant red and, like Prussian Blue, is considered an artist's color. It may be purchased at the local artist supply store in tube form. The substance is of little importance in the scraping art because the particle size, normally, is much larger than the Prussian Blue and consequently gives an inferior spread on a smooth work surface.

Sec. 10.30
Jeweler's Rouge

This is a reddish powder of fine particle size made from iron oxide. The method of preparation and use is the same as for Red Lead.

Chapter 11

MARKINGS

In this chapter are discussed methods of analyzing the markings resulting from the spotting process. However, there is no assurance that this analysis will be correct unless the work surface is first stabilized. Consequently, it should be the foremost concern of the operator to achieve this condition promptly. The following sections are devoted to explaining these subjects which are closely related.

Sec. 11.1
Analysis of the Markings on the Work Surface

It is important for the scraping specialist to understand the significance of the various colors of the markings as they appear on the work surface after it has been rubbed by the spotting tool. During the early stages of the job, the quantity of marking compound applied to the test gage is greater than when the scraping is well advanced. As a consequence, the marks disclosed during the initial cycles are of one color. (A few isolated high spots may constitute an exception but, since this condition will not affect the general rule, it will be disregarded during the present discussion.) As the scraping progresses, and the quantity of marking medium applied to the surfaces is gradually reduced, differences in coloring of the marks will become noticeably apparent.

Close observation and correct interpretation of these markings speed the work and improve its quality.

Deposits of natural color, red, blue etc. i.e., the basic hue of the compound being used, signify that the work surface underneath is flat or possibly even concave. Lighter tints intermingling with the natural shade denote slight underlying convex irregularities. Markings of a brownish tinge interspersed among the other shades indicate roughnesses in still higher relief. Shadings of all gradations will be seen during the intermediate scraping cycles, merging into one uniform tint as the surface is scraped flat. At the scrape-finished stage the coloration, though uniform, will be more or less pale depending on the thinness of the marking film.

A little reflection discloses what causes the brownish discolorations to materialize when the work surface is nearing completion. With a relatively uniform bearing plane, each high spot is colored the natural hue of the marking medium transferred to it by the testing gage. In such a case the tool deposits the coating of compound onto so many irregularities, representing in the aggregate a considerable area, that the pressure per square inch is relatively light. As a result the marking medium is not squeezed off of the high points. On the other hand, when the inequalities are few in number and small in size, the pressure on each one increases proportionately. Consequently, the weight of the heavy spotting tool is too much for the film of marking medium to support. The pressure ruptures the film. Then the tool and the work surface are brought into a metal to metal contact causing the discoloration. Incidentally, this explains why burrs are so very dangerous and so apt to ruin a good testing gage.

When both naturally colored marks and brownish marks appear simultaneously on a work surface only the latter should be scraped. After this is done the work surface is wiped clean. At the next application of the compound, the markings will appear more uniform in coloration. This indicates a truer surface.

Just as it is essential for the bearing spots to be uniformly high, so it is equally necessary that the bearing spots be evenly dispersed. The only way to determine this is by the appearance of the marks. Similar coloration and overall distribution, as judged by a well trained eye, indicates

that the bearing spots have the desired characteristics. As time goes on, the novice will acquire a sense of color value and be better qualified to evaluate the markings.

Sec. 11.2
Analysis of the Markings on the Spotting Tool

As we have mentioned previously the usual way to detect high spots is to observe the markings formed on a work surface by the transfer of compound from a spotting tool. Considerable emphasis has been placed on correct analysis of these markings. This is justifiable because much can be learned about a surface by studying the indicated high spots.

However, the markings on the work surface do not always provide an accurate picture of conditions. There are several reasons for this. In the first place, the spotting tool may have been rubbed on the work surface for an excessive time. While some of the compound transfers to the high spots, the markings are distorted because even more compound is forced down into the adjacent low areas. Another factor contributing to error, because it exaggerates the size of the markings, is a surplus quantity of compound on the surface of the testing gage. A further cause of inaccurate markings is an over-extended movement of the spotting tool. The longer the stroke the more compound is stripped off. This is the reason why it is repeatedly urged that the length of the rubbing movement be curtailed to the minimum.

Experienced scrapers understand how easy it is to misjudge the character of a work surface, especially during the early stages, by wrongly interpreting the size and location of the markings. Therefore, to avoid scraping low areas filled with compound to an even greater depth, the true condition of the work surface is cross-checked by also inspecting the markings on the gage. This is done after the STRAIGHT EDGE or SURFACE PLATE is separated from the work piece. The tool's surface formerly coated with compound is rubbed clear where it has been in contact with the roughnesses on the work surface and partially cleared off by other inequalities not quite so high. Translating these clear marks on the tool, in terms of irregularities on the work, the operator easily locates the true high spots and discounts those marks where the compound has filled in low areas.

The operator should train himself to identify and interpret significant changes in the film of marking compound coating the tool surface. Frequently, the impression gained from such a study is more informative than an equally close scrutiny of the markings appearing on the work surface. This advantage holds during all stages of the job.

The study and analysis of a tool, after the marking compound has been transferred, is especially recommended as a method for the rapid detection of scattered and inconspicuous burrs. For example, assume a certain work surface has been nicked but the extent of the damage has not been fully ascertained. It would be a very tedious job to explore the entire area, particularly a large one, in order to locate the offending burrs. The reason for the difficulty is that the few irregularities may be so small as to be practically indistinguishable from the remainder of the work surface. Their coating of marking medium makes their concealment even more complete. Under these conditions, only a keen eye is able to detect the burrs readily by scanning the work surface. Better results are possible if first the tool is examined.

Sometimes only a single, small high spot or burr holds the tool from intimate contact with the work surface. It may be so diminutive as to be all but invisible to ordinary inspection. Not infrequently it is the direct cause of the novice operator heavily scraping unoffending portions of the work surface in the erroneous belief that they represent high areas. It may take the more obtuse mechanic several scraping cycles to realize that something, somewhere, is wrong when no improvement is noted.

Having learned this from experience, the expert scraper will, in addition to inspecting the markings on the work surface, always glance at the coated surface of the spotting tool immediately after transferring the compound by rubbing. The appearance of a narrow streak on the tool surface, or sometimes a clear spot, establishes the presence of a burr. By

correctly translating distances and directions on the gage surface, in relation to the work surface, the location of the offending burr is quickly determined. Time and effort can be reduced, and possible damage to the tool avoided, if this practice is routinely followed.

While it is a fact that the transfer of the compound cannot be accomplished without some change in the film on the tool surface, nevertheless streaks do not logically belong there. Therefore, if a burr cannot be found after a close examination of the work surface, the streak might just as likely be caused by a particle of foreign matter. When the operator entertains that opinion, both of the surfaces should be thoroughly cleaned and a fresh start made.

Sec. 11.3
Stabilized Conditions

A stabilized condition is said to exist when it is possible to produce with a SURFACE PLATE, STRAIGHT EDGE or other spotting tool or template, a pattern of markings that truly indicates the high spots on a work surface. It means obtaining conditions wherein the medium transferred by the spotting tool actually represents irregularities. In other words, when the colorations appearing on the work surface are repeated consistently both in form and location in consecutive applications of the spotting tool, the markings are reliable.

It should be understood that we do not mean there is no variation whatever in the pattern. Some modifications from cycle to cycle, as the result of scraping, is implied. Excepting slight changes, reasonably expected from the scraping effort, any radical shift in the position of the markings during successive applications of the spotting tool, is indicative of instability and correct steps should be undertaken.

Merely placing a SURFACE PLATE on a piece of work and rubbing it back and forth a few times is no guarantee that the markings thus formed will provide a true picture of the character of the work surface. Scraping is never an automatic process, even though observing the actions of a skilled worker might tend to leave that impression with the uninitiated. It requires intelligent use of tools and constant vigilance in analysis, first to secure, then to maintain a situation where the markings will be stabilized.

In scraping parlance, a surface that "Won't lie down" denotes instability. It is recognized by areas which after being spotted and scraped do not reappear at the next cycle in improved form, as could normally be expected. Instead the high part, as indicated by the markings, suddenly shifts to a different portion of the work surface. On scraping this new location, the markings disappear only to reappear at the next cycle where originally observed, or possibly at still another place.

The occurrence of this phenomena is not ordinarily as dramatic as described above, but it happens occasionally. Usually, however, it is an insidious state which comes slowly into being and it is not until after considerable scraping has been done that the novice scraper realizes that something is wrong and hastily takes steps to discover what it is.

Stabilized markings are highly desirable to the scraping operator because the attainment of this condition expedites his work. One of the errors, most wasteful of time and effort, is the failure to stabilize the markings on the work surface as promptly as possible. It is the inability to understand the true state of the work surface that is at the root of the trouble and the misapplication of the spotting tool simply aggravates the situation.

Sec. 11.4
Cause of Unstabilized Conditions

The chief cause of unstabilized conditions is a convex work surface. The gravity of this defect and the frequency it is encountered makes it desirable to discuss it at some length. A secondary cause of unstabilized conditions could be the unmethodical application of compound in non-uniform films. Rather than risk repetition, the reader is urged to review data contained in Sec. 10.5.

Convex surfaces are often formed on slides and ways of machine tools as the result of natural wear. In the matter of the sliding member, this deterioration is caused chiefly by dust and grit getting under the wipers and attacking the

extremities of the slides.

As regards the stationary member, the harm results principally from the increased pressures per square inch on the ways, and the consequent destruction of the oil film which occurs when the sliding member overhangs the ways at the end of a traverse. Except for careful adjustment of the wipers, and adequate lubrication of the bearing surfaces, little can be done to slow the trend.

In addition to this natural or spontaneous formation seen on surfaces in need of reconditioning, convex curvatures are also generated by faulty scraping and improper spotting methods. Although skill, derived from experience, will do much to prevent such mistakes, even experts encounter difficulty on this score. Without theorizing as to causes, it is definitely known that there is a universal inclination to scrape, both harder and deeper, near the edges of a work surface than in the center. This leads to the creation of a high middle area. By improper manipulation of the spotting tool, which subject is discussed in Secs. 8.11 and 9.3, this tendency is aggravated.

The vast majority of scraping jobs, and this is especially true of rescraping machinery, will involve reducing a convex surface to a flat condition. Whether it is a flat way, a dovetail, or a V-way, it is usually the ends of the bearing surface that will wear the most. The problem essentially is to scrape the high middle area level with the ends, while giving to the whole an adequate surface bearing quality. A convex surface is then the chief cause of unstabilized conditions. It acts as a pivot point for the SURFACE PLATE or STRAIGHT EDGE. Refer to Sec. 11.7 (Choosing the advantageous side of the work piece.)

The defect usually occurs in an area approximately at the middle of a machine bearing surface. The only exception is when it is caused by warping. If, as the result of the warp, a convexity is generated, the high area will naturally occur at the point where the strain distorted the casting.

It is obvious that if the convex area or pivot point is nearer one end of the work surface than the other, the tool, whether SURFACE PLATE or STRAIGHT EDGE, will be unbalanced when placed thereon. That is, the pivot point divides the tool into two unequal lengths. The longer part will rest on the surface at one side of the pivot while the shorter end of the tool will be, more or less, up in the air on the other side. It is, in other words, just a simple case of balance.

The closer the pivot point is toward either end of the work piece, the easier it becomes to locate it and secure stabilized markings. Conversely, when the position of the pivot point is at the approximate center of the work piece, the greatest difficulty will be experienced in detecting it and in obtaining stabilized markings.

Sec. 11.5
Prolonging Unstabilized Conditions

Improper manipulation of the spotting tool will prolong the unstabilized condition of a surface. On a convex surface particularly, it will produce some rather astonishing, and always inaccurate, results. In these circumstances, unstabilized conditions are inevitable. For example, if the pivot point is off-center it is incorrect to grasp the short end of the tool to spot the surface. (i.e., short as measured from the pivot point) This necessitates pressing the short end down with some force, to bring it into contact with the work. The long end is thereby elevated.

If it were possible always to balance delicately the long end of the tool in the air away from the work surface, no harm would result from improper handling, and the convex middle area or pivot point would be gradually reduced. However, the convexity of the work surface may be so slight, only a thousandth of an inch or so, that the operator will be unaware that the ordinary pressure on the short length of the tool has not completely raised the longer half away from the surface. Possibly during one or two strokes, and without the operator knowing it, the short section of the tool was not in contact with the surface, even though manipulated from that end. Consequently, after the tool is rubbed back and forth a number of times, a set of markings will appear on both sides of the pivot giving a false impression of the surface condition.

NOTE: A heavy coating of compound thicker than the pivot point is high would

produce the same effect by causing the tool to spot simultaneously on both sides of the pivot.

If this incorrect method of tool handling is persisted in, the pivot point will creep, more or less, and the markings that are produced will be strange and unfamiliar. In other words, each time the tool is applied to the surface, the markings change form, or position or both. No definite trend is observable, and scraping fails to produce a flatter surface.

NOTE: It might be appropriate to interject here that in spotting a convex surface the correct handling of either SURFACE PLATE or STRAIGHT EDGE should be from the longer side, as measured from the pivot point. That is to say, the tool is grasped at one end only and this end should be the one farthest from the pivot. This is discussed more fully in the next section.

An unstabilized condition on a work surface may be produced quite unintentionally by an operator. Basically it results from mishandling the spotting tools, especially the STRAIGHT EDGE. Improper manipulation of a tool invariably generates a convex surface which is the cause of the unstabilized condition.

For example, if we wish to produce a better bearing on a long narrow work surface and the STRAIGHT EDGE is selected for spotting, it should never be grasped at both ends or by both handles when transferring compound. If grasped this way, pressures are applied at the extremities of the tool causing it to bow and consequently to mark the surface more heavily towards the ends. Thus even if the original surface was fairly flat to begin with, several cycles of spotting and scraping would generate a convex curvature which would become progressively worse the longer it was treated. The trend is easy enough to see.

The formation of a convex surface is accelerated by applying a slight pressure to both handles. This would not happen if the tool were held correctly at one end only. It may be advisable for the reader to refresh his memory by rereading Secs. 9.3 and 9.4. (Handling the STRAIGHT EDGE) for here is an error that the novice occasionally slips into.

This lapse from good practice is most likely to occur when the film of marking compound on the tool is not commensurate with the requirements of the work surface. When the medium is too thin, the markings formed are very light in coloration. To obtain a more conspicuous marking, the operator applies, perhaps unconsciously, a slightly heavier pressure to the tool or prolongs the rubbing and thereby initiates a chain of events culminating in an unstabilized condition on the work surface.

Sec. 11.6
Stabilizing Procedure

The task of stabilizing the markings on the work surface is handled differently according to whether;

1. The work piece is placed on top of the tool i.e., the process known as spotting.
2. The SURFACE PLATE, STRAIGHT EDGE or other spotting tool is laid on top of the piece of work i.e., reverse spotting.

When the work is placed on the SURFACE PLATE (NO. 1 above) perhaps the best approach is as follows:

The work piece is examined for signs of wear. If the deterioration is most conspicuous at the ends, it suggests that the middle area is probably high i.e,, convex. When the areas of major abrasion are not noticeably apparent, the Spin Test, is applied to locate the pivot point.

Having investigated and obtained tentative answers to the preceding survey, the work piece is laid on the SURFACE PLATE. Now comes the very important decision of where to place the hands while rubbing the work piece back and forth on the tool. The correct choice of position is located as follows:

Sec. 11.7
Choosing the Stabilizing Side of the Work Piece

When the high area or pivot point is very close to the center of the work surface, as determined by the Spin Test, the operator may grasp the work piece from any side, but once the choice is made it

must be kept until the job is completed. In other words, there can be no alternation.

Should the pivot point be closer to one side or end of the work piece, it is the opposite end or side that must be gripped. It is often advisable to chalk or otherwise indicate this side so no mistake will be made during the course of the spotting.

The operator may be certain that he has selected the correct side of the work to take hold of, if after spotting and scraping the work several times, the markings appear to have stabilized. In other words, the markings should reappear consistently after each spotting cycle in the same places and in approximately the same form. Of course, there is some change or improvement in the appearance of the markings as a result of the scraping performed but it is not abrupt.

On the other hand, if the marks shift their location, appearing and disappearing mysteriously, or change form radically in successive cycles, it is obvious that the selection was ill advised. In such a case conditions must be re-examined and a new and more effective position found.

If the initial selection has been made judiciously, it is not often that a substitution will be necessary, unless the operator becomes careless and allows a new high area to develop. Constant vigilance is the only way to preserve stabilized markings.

In the other method (NO. 2 above) technically known as reverse spotting, the SURFACE PLATE or STRAIGHT EDGE is applied to the work. The procedure of finding the correct position from which to work is somewhat different with this system, as can be seen from the following measures which are taken.

1. The Spin Test is applied where feasible to ascertain the location of the pivot point. Then the tool is grasped at the end of its longest arm i.e., that end which has the greatest length beyond the pivot point as it rests on the work surface.
2. The operator should always resume this same advantageous position with reference to the work piece each time the tool is reapplied to the surface. If this is done the long end of the spotting tool will automatically be grasped. To avoid confusion this side of the work piece should be identified with some distinguishing sign.

The procedure above outlined should be strictly followed since it is not at all difficult to cant a spotting tool on a crowned surface. Novice scrapers, sadly enough, quickly learn this to be a fact. Should the operator thoughtlessly place himself each time at a different side of the work, an unstabilized or variable form of marking may result. In other words, it is not permissible to apply the spotting tool indiscriminately from just any side of the work piece. For example, if we start our reverse spotting while working from a certain side, we must continue from that side until the job is done.

If the work surface is crowned, and no effort at stabilization is made, the markings indicating the high areas may appear at a different location at each spotting cycle and no general trend will be observed. The inconclusiveness of his efforts may not immediately be perceived by the scraper, particularly if he is not keenly observant and possessed of a good memory. To minimize such a possibility, which makes for much fruitless labor, and to avoid the detrimental effects of many distractions, some operators resort to the control system known as the Markings Chart.

Sec. 11.8
The Markings Chart

A Markings Chart is simply a sketch drawn, say, on paper to depict the location and outline of the areas of marks which appear on the work surface after applying a spotting tool. The purpose of the Markings Chart is to assist the memory of the operator with respect to the position of the high areas on the surface. In effect, the Charts advise whether or not the surface is stabilized.

By referring to the diagrams he has drawn, the operator can analyze the progress of the work from cycle to cycle and will be able to forsee the course of the work. With this information, it is safe in some infrequent cases to adopt off-hand scraping to expedite the job. (See Sec. 6.12)

The Markings Chart is not the solution to nor a guarantee of good scraping results, but it is a convenient aid to memory. Consider for instance the fact that a scraping assignment is not always carried through to a swift conclusion. Other more pressing work sometimes intervenes, or a week-end or holiday shuts down the shop. When operations are resumed, the Charts will reveal what has been accomplished and eliminate the need for re-examining work previously performed.

Once the trend of the scraping is known and the surface is stabilized, the charting may be discontinued. This is usually after four or five consecutive applications of the marking medium.

In drawing the Charts, any convenient scale is satisfactory because nothing has to be precise. It may be the crudest approximation so long as it indicates roughly the information desired. The preparation of the diagrams is co-ordinated with the scraping. Each time as the surface is spotted, the Chart is sketched in on any convenient piece of paper showing the location and outline of the marked areas.

It should be realized that in the early stages of spotting the marked areas are of some size, and not minute dots, as is the case after the surface has been scraped relatively smooth. Consequently, it is entirely practicable to prepare a Markings Chart at the start of a job and obviously impracticable later on when the drawing of such a diagram would involve too much detail.

The Charts are more valuable for use with large surfaces than for small ones simply because on the former there is more to remember. The Charts also provide assistance when working with tools of inadequate size. For example, applying a STRAIGHT EDGE to a very long surface necessitates laying the tool in two or even three steps in order to cover the whole. This procedure has been explained in Sec. 9.7. However, we might state briefly that under these difficult conditions, portions of the markings must be cleaned away so that the compound from each application of the tool will not be in layers. The Chart provides the necessary information as to the general surface condition.

When utilizing the principle of the Symmetrical Distribution of Errors, say to generate three SURFACE PLATES from machine-finished castings, the Markings Chart is also helpful. (See Sec. 21.4)

Chapter 12

OTHER SPOTTING TOOLS

To supplement the conventional spotting tools it will often be necessary to make up special gages to cope with the various problems encountered in reconditioning precision machines. Important in this category are templates which take several forms. They may be classified first, into templates which spot two ways (or slides) simultaneously, thereby maintaining center to center distances. These templates are comparatively large and heavy. The other classification is referred to as hand templates, which inferentially denotes their size.

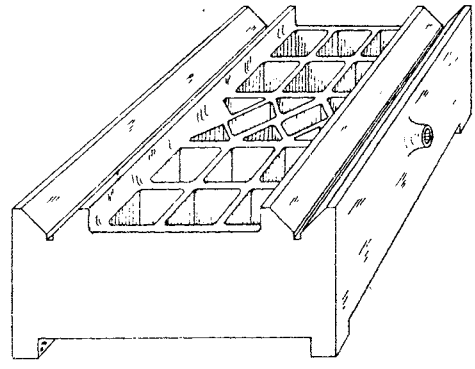


Fig. 12.1 Typical form of template used to spot bottom bearing surfaces of carriage of surface grinder. To detect warping in a template of this type, a SURFACE PLATE can be used as a base plane.

Sec. 12.1
Templates

In scraping terminology, templates are metal patterns. Usually they are of cast iron, well ribbed, heat treated, and pin point hand scraped. Templates are precision gages and must be handled with the same care given to other spotting tools, such as SURFACE PLATES, etc. The scraped surfaces of the template are used primarily to spot the ways and slides of machine members so that they may then be scraped to conform to a definite standard.

In addition to functioning as an accurate spotting tool, templates are designed to indicate such vital points as:

1. The angular value of a bearing surface, such as a V-way or dovetail.
2. The tilt of a bearing surface with reference to an adjacent bearing surface.
3. The determination of the center-to-center distance, as, for example, between two V-ways.

When the template is made big enough to cover the several bearing surfaces of a member at one lay, no other spotting tool is required. (See Fig. 12.1) It should be understood, however, that a template need not be so large as to cover completely the bearing surface it is spotting. A size sufficient to maintain angles and preserve center distances etc. is all that is necessary, provided supplementary spotting is executed with standard spotting tools. Essentially, as far as the scraper is concerned, templates are merely oddly shaped, or non-standard spotting tools.

As a rule, the template will not generate an alignment automatically. The operator must execute his scraping so that the bearing surfaces are tilted in the proper direction. And of course, the usual alignment tests must still be conducted when needed.

Sec. 12.2
Machine Members as TEMPLATES

Machine members are often utilized as templates to spot other machine members on which they slide. This practice is quite common in the reconditioning of machine tools in the average shop. To initiate the system, one member of the machine is spotted with standard spotting tools, and when completed is used as a template for the member it is mated with. That

member in turn acts as a template for a third part etc. This technique is unquestionably the simplest and least expensive way to fit two mateing parts.

However, when attempting to match the ways and slides of large, heavy machine members it is often more efficient to prepare special templates even though this involves additional scraping. In many cases, such a course is necessary because there is a lack of adequate hoisting equipment for handling massive castings.

Actually in making such a template, two patterns must be constructed to transfer the dimensions of one machine member to a second member. The procedure would be as follows:

The bearing surfaces of the first member are developed to the desired bearing quality. Simultaneously, the angular value, the correct alignment etc., of the bearing surfaces are produced and the center-to-center distance, such as between two inverted V-ways, is established. A pattern, call it No. 1, is made up and fitted to the scrape-finished member. Then pattern No. 1 is utilized to form the desired dimensions on another metal pattern designated template No. 2. Template No. 2, when completed becomes the actual tool which is employed to spot the second machine part. Template No. 1, having no further useful purpose, is discarded immediately when template No. 2 is finished.

For example, assume it is desired to scrape the bearing surfaces of machine member (B) to fit member (A) as represented in Fig. 12.2. And further assume that for good and sufficient reasons, one member cannot be directly applied as a template to spot the other. To cope with this problem two templates are required to transfer the surface bearing dimensions. The procedure is as follows:

After machine member (A) is scrape-finished, template No. 1 is scraped to match it. Then template No. 2 is made up and fitted to the first template, following which No. 2 is used to spot in member (B). Finally, when (B) is completed it may be placed on (A) with complete assurance that the bearing surfaces will match. Incidentally, in manufacturing processes, these are two commonly used techniques. First, templates are constructed to spot the bearing surfaces of machine members. Second, a scrape-finished part is employed to spot its mateing member.

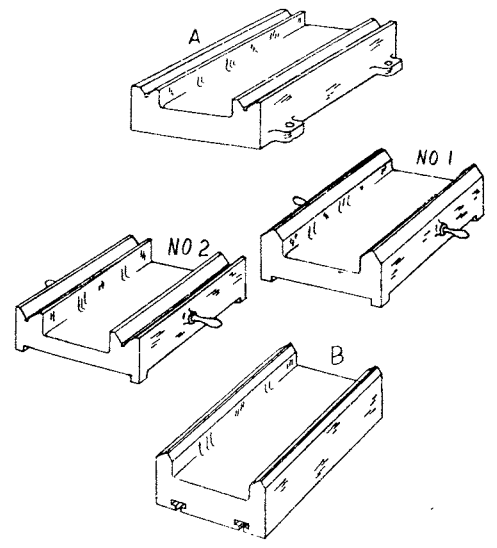


Fig. 12.2 Diagram illustrating the several steps required in matching bearing surfaces of casting (B) to bearing surfaces of casting (A), assuming they cannot be placed directly together. Templates NO. 1 and NO. 2 represent intermediate stages in the fitting process.

Sec. 12.3
Hand Templates

In addition to the large pattern noted above, templates are also made in the small hand size. They are constructed in several different forms, each being suitable for only one type of bearing surface. For easy identification they are named for the kind of surface they are applied to. Detailed descriptions of various applications are reserved for later paragraphs.

Small hand templates are preferred for the occasional job, as they eliminate the need for the large template designed to cover the entire work surface. The latter require considerable labor to make, while the small hand templates are produced in a fraction of the time.

Their principal use in spotting work is to furnish the desired angle. This they do effectively. Due to limitations of size, however, they do not indicate flatness accurately. To compensate for this inadequacy it is common practice to alternate them with a standard spotting tool sufficiently large to cover the entire surface at one lay.

Sec. 12.4
Right Angle Template

The right angle template, which derives its name from the 90° separation of its spotting surfaces, is a very efficient tool in producing a square edge on a piece of work. With it, the operator is able to spot accurately while maintaining one surface square with an adjacent surface. Besides being convenient to apply, it is simple in design and easy to construct. On many scraping jobs it is practically indispensable, and the operator will find the time and effort in making one well spent.

The right angle template performs three functions that expedite the scraping operation, viz:

1. By transferring marking compound, it provides visual indication of high spots and areas out of true.
2. It maintains a constant angle between one surface and an adjacent surface.
3. It produces an area contact, which is more reliable than the line contact of a vernier protractor or a tool maker's square.

Sec. 12.5
Specifications

When specifying the dimensions for a small template, the angle (x) is based upon the work surfaces it is applied to. The other dimensions are a matter of choice. The following table indicates the general requirements for a template used to spot square edges.

L	Length, sufficient to overlap slightly the surface being spotted.
W	Width, adequate to provide stability to the gage
L'	Length, proportionate to other dimensions, to furnish balance to the tool.
X	Angle between critical spotting surfaces
M & N	Contact surfaces scraped to SURFACE PLATE quality.
M'N'	Reverse surfaces sometimes also hand scraped.
G	Groove
T	Thickness, about 1".

Fig. 12.3 shows the template in completed form. The tool is made from a cast iron block, machined to size, and hand scraped. There are no hard and fast specifications for size. A template 4" on a side will be adequate for most jobs.

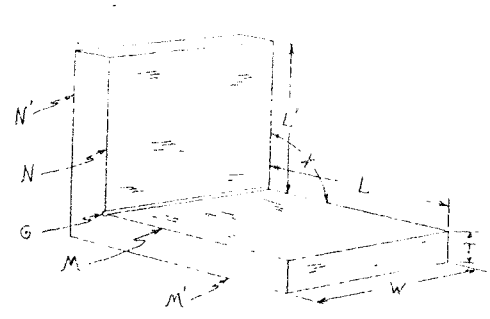


Fig. 12.3. View of right angle template.
(M and N) inside scraped surfaces (M' - N') outside scraped surfaces (L - L') length (W) width (T) thickness (A) angle (90°) (G) groove

Sec. 12.6
Applying the Right Angle Template

One of the scraped faces of the template is used to spot the work surface, the other face is held flat against the adjacent scrape-finished side of the work. The gage is rubbed back and forth to transfer the compound. Any variation from a right angle is indicated by the markings. This subject was discussed fully in Sec. 10.11 (Interpreting the Markings).

Returning to Fig. 12.3 we see that pin point hand scraping the outer surfaces (M')-(N'), as well as (M)-(N), will provide the right angle template with a dual utility. If the outer surfaces are used, an inside corner can be spotted. By using the inner surfaces it can be applied to a square edge. (See Fig. 12.4)

Sec. 12.7
Obtuse Angle Template

The obtuse angle template is often useful in developing identical angles on angular bearing surfaces. The form illustrated in Fig. 12.5 is made of cast iron in one piece. After finish-machining, the contact

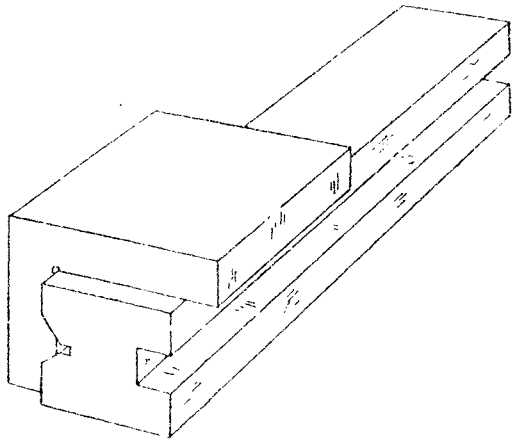


Fig. 12.4 Showing application of a right angle template to a square edge.

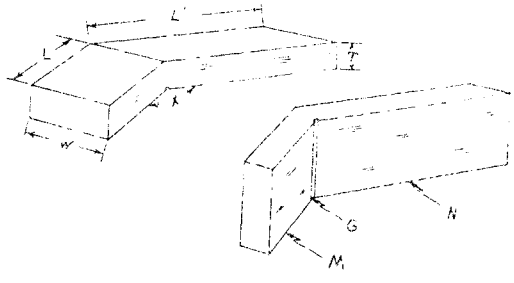


Fig. 12.5 Obtuse angle template.

(M and N) scraped surfaces (L - L') length (W) width (T) thickness (G) groove

surfaces are scraped to a SURFACE PLATE quality. At the same time an exact, predetermined angle, always more than 90°, is developed. Referring to Fig. 12.5, surface (N) is designed to guide, and surface (M) to spot the work piece. Fig. 12.6 illustrates the obtuse angle template in operating position on the angular Way of a work surface. To spot the other angular Way, the gage is reversed.

Sec. 12.8
Dovetail Templates (Male & Female)

The operator has frequent occasion to make up dovetail templates of both the male and female type. Fundamentally, the only difference between the two is in the spotting surfaces. In the case of the male dovetail template the scraped surfaces

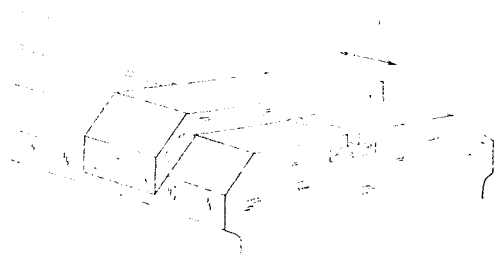


Fig. 12.6 Showing application of obtuse angle template for spotting an angular way. Device keeps both inclined surfaces at same angle with respect to flat way.

used for spotting are the exterior faces. See (M) and (N) in Fig. 12.7. The method of use is represented in Fig. 12.8. Female dovetail templates, on the other hand, are scraped to high bearing quality on the inside faces, which are then employed for spotting purposes. Refer to Fig. 12.9 and Fig. 12.10.

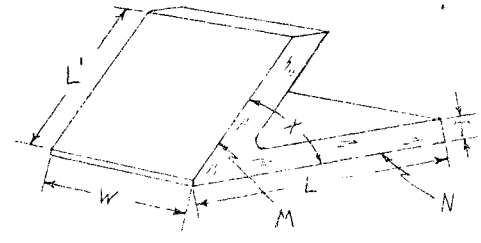


Fig. 12.7 Male dovetail template having blunt edge.

(M and N) scraped surfaces (L - L') length (W) width (T) thickness (X) angle

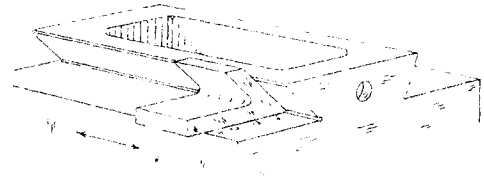


Fig. 12.8 View of male dovetail template spotting a dovetail.

Making a dovetail template, either male or female, begins with the determination of the correct angle. This, obviously, is taken from the dovetail of the machine member being reconditioned. The other dimensions are then selected and the

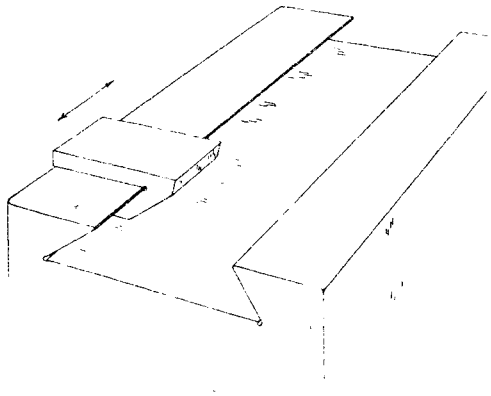


Fig. 12.9 Showing female dovetail template spotting.

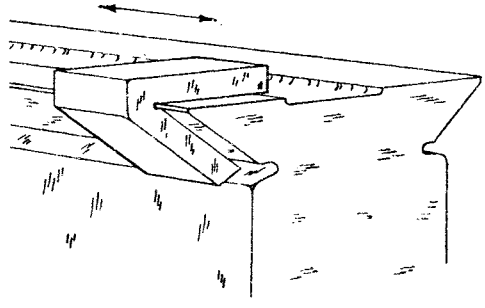


Fig. 12.10 View of female dovetail template in spotting position.

template is machined from a piece of cast iron. Then it is pin point hand scraped.

It will be noted that the template resembles closely a segment of an ANGLE STRAIGHT EDGE, but it does have one important difference. The template is scrape-finished to the exact angle that is required for the dovetail of the particular machine member being reconditioned, whereas the ANGLE STRAIGHT EDGE is usually made so that it is adaptable for inclusion in dovetails deviating from standard.

Sec. 12.9
V-Template

Scraping operations on V-ways are facilitated when spotting is executed with the V-template described in the following pages. This tool, shown in the accompanying Fig. 12.11a, performs four functions in connection with V-ways, viz:

1. As a spotting tool it maintains a definite included angle between the two angular sides of the V-way.
2. In combination with a PRECISION LEVEL it is used to determine if a perpendicular line will bisect the angle of the V-way. The purpose of this operation is to learn if the V-way is tilted. (See Fig. 12.11b)
3. Again in conjunction with a PRECISION LEVEL it is used to detect any deviation of a single V-way from levelness in the longitudinal direction.
4. With a PRECISION LEVEL it is used to compare parallelism in the vertical plane of a single V-way against another bearing surface.

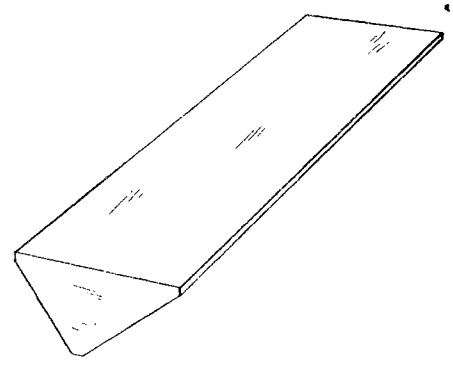


Fig. 12.11a Showing form of V-way template.

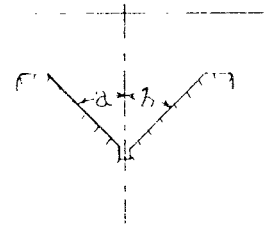


Fig. 12.11b Showing an essential factor in making templates for V-ways. Template must form the Vee so that a perpendicular line will bisect it. If angles (a) and (b) are equal tilt is eliminated and wear on each side is equalized.

Sec. 12.10
Construction of the V-Template

The first step in constructing the template is to decide on its angles and dimensions. A piece of cast iron is machined to conform as closely as possible to the outline shown in Fig. 12.12, wherein:

Z — Equals the angle of the V-way

X & Y — Represent equal angles

N & M — Are the pin point hand scraped spotting surfaces

K — The leveling surface (pin point hand scraped)

h — Equals the height of the template. Make an allowance for surface K to project above the V-way so that a PRECISION LEVEL may be placed on it cross-wise.

L — Any convenient length between 6" and 18".

F — A flat edge about 1/8" wide.

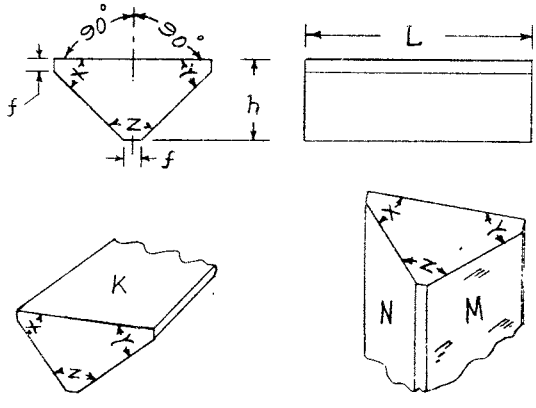


Fig. 12.12 Showing essential dimensions of a V template.

(Z) equals angle ot the V-way (X and Y) represent equal angles (N and M) denote pin point hand scraped spotting surfaces (K) scraped leveling surface (h) equals the height of template (L) length (f) flat edge

After machining the block, the next step is to scrape the essential surfaces to SURFACE PLATE quality, and to obtain the exact angles; i.e. angle (X) to equal angle (Y). Surfaces (K), (M) and (N), shown in Fig. 12.12, are scraped in any sequence desired. Either a vernier protractor or a sine bar may be used to measure the angles.

An alternative method which gives positive assurance that angle (Z) will be bisected by a line square with surface (K) is executed as follows:

First, surface (K) is scrape-finished. A female dovetail template is then made up to the proper angle by utilizing the following formula, viz:

Angular Value equals $1/2\ (180^{\circ} - Z)$

With this template laying from surface (K) as represented in Fig. 12.13b, surfaces (N) and (M) are spotted.

Sec. 12.11
Typical Set Ups with a V-TEMPLATE and a PRECISION LEVEL

After the template is completed it is utilized primarily as a spotting tool to maintain the specified angle between the two sides of a V-way. It may also be used in combination with a PRECISION LEVEL as follows:

1. To check a V-way for tilt, the template is inserted and a PRECISION LEVEL is set crosswise on top. (See Fig. 12.13a) If the bubble centers, the V-way has no tilt. In other words, an imaginary vertical line will bisect the V-way member making angles (a) and (b) equal, as indicated previously in Fig. 12.11b. Each side of the V-guide will thus carry an equal share of the weight of the sliding member. Uniform distribution of wear is the principal advantage of this practice.
2. By turning the PRECISION LEVEL by 90°, we may examine the V-way for levelness, longitudinally. The bubble must be centered to signify this condition. (See Fig. 12.14)
3. With this template it is also possible to determine if a V-way is parallel (in the vertical plane) with another bearing surface. In conjunction with a PRECISION LEVEL we can use it to check each of two V-ways independently. Then if the bubble centers on each,

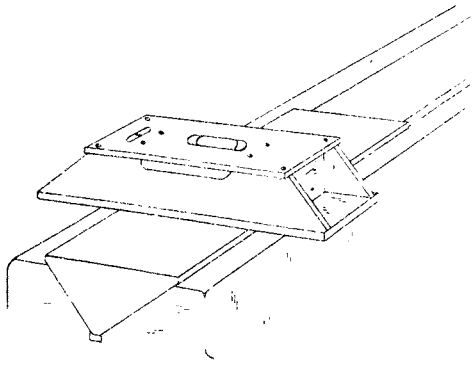


Fig. 12.13a Checking V-way for tilt using Template and PRECISION LEVEL.

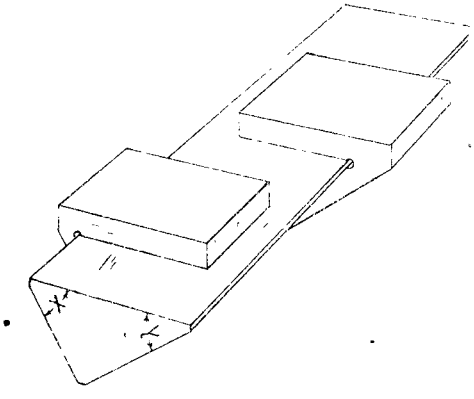


Fig. 12.13b Female dovetail template spotting a V-way template to insure that angles X and Y are equal.

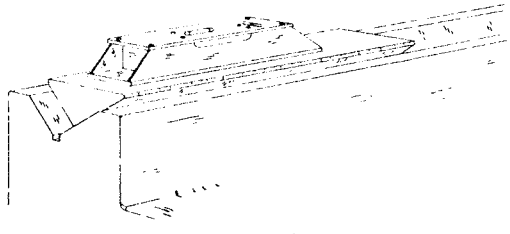


Fig. 12.14 Showing application of V-template for checking a V-way for levelness longitudinally.

we may be certain that they are aligned. Fig. 12.15 illustrates the application. In passing, it might be noted that the V-template cannot be employed to ascertain whether the two V-way bearing surfaces of the machine are parallel in the horizontal plane. Other methods must be employed.

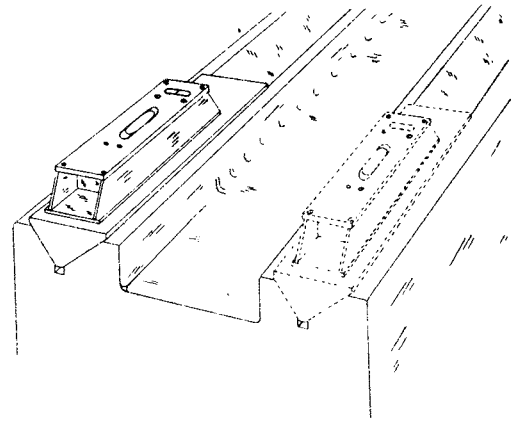


Fig. 12.15 Illustrating method of using V-template for testing the V-ways for parallelism in vertical plane.

Sec. 12.12
Inverted V-template

In order to scrape an inverted V-way (see Fig. 12.16) to an accurate alignment, it is necessary to make up a special precision testing tool, the inverted V-template. This gage is similar in design to the well known V-block, familiar to every machinist. By interposing this device between the angular sides of an inverted V-way and a PRECISION LEVEL, tests for levelness can be made which otherwise would not be possible.

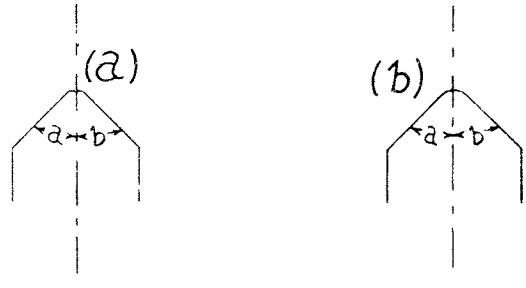


Fig. 12.16 Diagram of inverted V-ways showing types of leveling surfaces.

(a) flat top (b) rounded top

A novice scraper may be reluctant to expend the time and effort required to produce such a template for the specific job. It may seem unnecessary to devise a precision tool that is, perhaps, useful for just one occasion. However, there is no other way to obtain accuracy of alignment in such a work piece without first making a template. It is primarily because the scraping operator will be obliged to prepare, in the course of his work, many of his own tools and gages that their construction is described in considerable detail here and in other portions of this book.

When constructing such a template, the inverted V-way angle of the bearing surface of the member which is to be matched must be carefully measured. This angle is then reproduced in the template. The other dimensions are left to the judgment of the scraper. See Fig. 12.17.

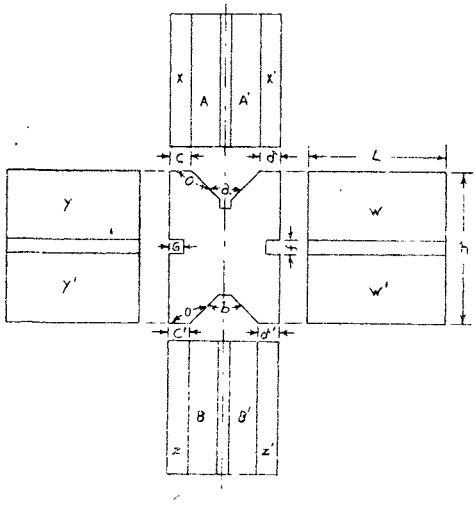


Fig. 12.17 Inverted V-template used for aligning operations on inverted V-ways.

(L) length (H) minimum height (F and G) dimension of groove for yoke clamp (Y and Y') dimensions determined by (H) (W and W') ditto (a) and (b) identical angles

DIMENSIONS:

L Length between 6" and 12"

H Minimum height to provide greater stability

F & G Dimensioned to receive a yoke clamp

Y-Y' Determined by dimension (H)

W-W' Determined by dimension (H)

a & b Identical angles.

Sec. 12.13
Constructing an Inverted V Template

When the V-angle of the template is decided on, a cast iron block is machined on the basis of this measurement. It is machined as closely to the required dimensions as possible, and then scrape-finished to the pattern shown in Fig. 12.17. One efficient method of producing this template is by the following procedure:

OPERATION NO. 1 Surfaces (X) and (X') are scraped flat and true using a SURFACE PLATE for spotting purposes.

OPERATION NO. 2 Surfaces (Z) and (Z') are scraped parallel to (X-X'). To check progress, lay the template on a SURFACE PLATE and measure for height to all corners with a DIAL INDICATOR affixed to a surface gage.

OPERATION No. 3 The inclined sides (A-A') are scraped. To assure that the angle "a" of the V is bisected, an obtuse angle template is made up to equal angle O. Lay this gage along surface (X) and spot side (A). Then support it on (X') and spot side (A').

OPERATION No. 4 The axis of the V formed by the junction of sides (A-A') must be aligned to surfaces (Z-Z') and (X-X') in the vertical plane. The set up to check this is given in Fig. 12.18. In brief, the V-block is set on a SURFACE PLATE with surfaces (Z-Z') in contact. A PRECISION CYLINDER is placed in the V. Measurements are made with a DIAL INDICATOR to points (M) and (N) on the CYLINDER. The readings must be zero-zero. Any deviation from alignment must be corrected before proceeding to the next step.

OPERATION NO. 5 To expedite the production of this inverted V-template only one of the two

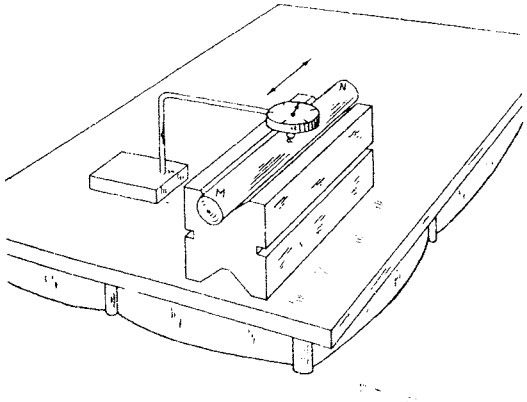


Fig. 12.18 Method of checking parallel alignment of axis of V-way in vertical plane. With surfaces (Z-Z') resting on SURFACE PLATE a zero-zero reading between points (M) and (N) is required.

sides, either (Y-Y') or (W-W') need be scraped. The other side may be ignored. In this discussion we will scrape side (W-W') only. Surfaces (W-W') are scraped square with (X-X') and (Z-Z'). A useful spotting tool will be the right angle spotting template mentioned previously. While this work is being carried on, the operator is obliged to make checks for alignment as follows:

Check the alignment of surfaces (W-W') with the axis of the V (a). This operation is illustrated in Fig. 12.19. In checking the alignment of surface (W-W') to the axis of the V(a) the template is turned so that surface (W-W') rests on the SURFACE PLATE. Measurements taken at points (M) and (N) on the test bar must be zero-zero to indicate correct alignment of surface (W-W') to the axis of the V-way.

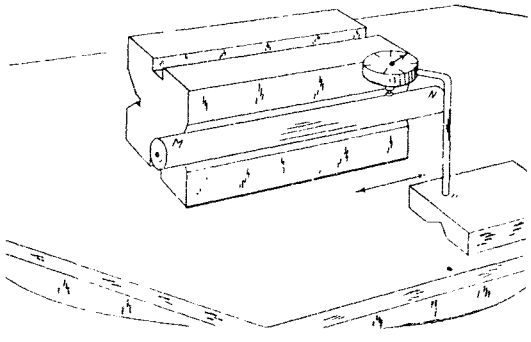


Fig. 12.19 Checking parallel alignment of surfaces (W-W') to axis of the V-way. With surfaces (W-W') in contact with SURFACE PLATE, test bar must test zero-zero at (M-N).

OPERATION NO. 6 Sides (B-B') of the V (b) are spotted using the obtuse angle template previously constructed. When these surfaces are finished, angles (a) and (b) are equal. In addition to good surface bearing, the axis of the V (b) must be aligned with the axis of the V (a) in both the vertical and horizontal planes. The manner of testing the alignment in the vertical plane is identical to that illustrated in Fig. 12.18, except that now the test bar is inserted in the V-(b) and the template rests on surfaces (X-X'). The check for the alignment in the horizontal plane is a duplicate of Fig. 12.19, except that in the present instance the test bar is inserted in the V (b).

Scraping continues on the V (b) until these conditions are satisfied.

NOTE:

The inverted V-template is made singly unless the member being scraped-in has two inverted V-ways. In that case, two identical gages are constructed.

Although producing an inverted V-template is a sizeable undertaking, the sequence of operations just outlined should expedite the job. Once prepared, a gage may be used for many essential checks, and in that way, will assist in bringing the work rapidly to completion. The advantages it offers far outweigh the effort to construct it.

Sec. 12.14

Functions of the Inverted V Template

(Employing one gage and suitable auxiliary apparatus)

1. To maintain a definite angle for the sloping sides of the inverted V-way.
2. To assist in aligning the inverted V-way so that a vertical line will bisect the angle, thereby preventing tilt.
3. To test levelness, longitudinally.
4. To determine parallelism in the vertical plane between the inverted V-way and another form of bearing surface.

(Employing two gages and other apparatus)

1. In conjunction with a PRECISION LEVEL and CYLINDER, to test two inverted

V-ways for parallelism in the vertical plane and for levelness in the transverse and longitudinal directions. Refer to Fig. 25.36, Fig. 25.37 and Fig. 25.38.

2. Jointly with a DIAL INDICATOR, a PRECISION CYLINDER, and a dummy spindle test bar, to check two inverted V-ways for parallelism in the horizontal plane. See Fig. 25.39.

Sec. 12.15
Simple Inverted V Template

The complex gage described above may under some circumstances be produced in a simplified form as shown in Fig. 12.20. When this is feasible, both time and effort can be saved. The opportunity is presented when the gage is to be used principally for spotting purposes. This eliminates as critical constructional requirements all but the development of an angle of definite value.

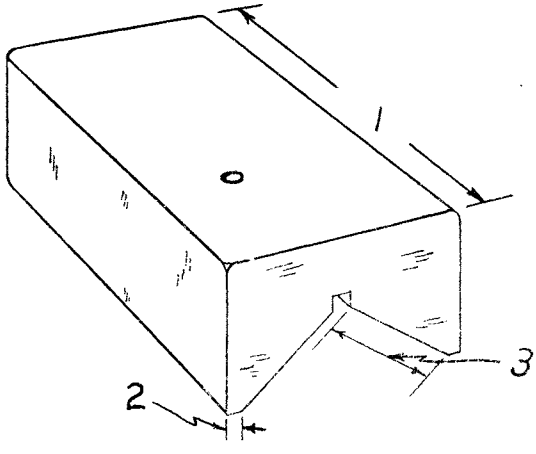


Fig. 12.20 Simplified version of inverted V-template.

(1) length 6" to 8" (2) minimum width flat to clear obstruction (3) angular side dimensioned to overlap V-way

To produce this version of the inverted V template proceed as follows:

A block of cast iron 6" to 8" long is procured. Its width and thickness will be governed by the size of the inverted V-way. The block is finish-machined and a V is cut in it to correspond to the desired angle. The only treatment necessary will be on the two sides of the V which are scraped to SURFACE PLATE accuracy. Spotting can be performed with an ANGLE STRAIGHT EDGE. To maintain the proper angle, measurements are occasionally made with a vernier protractor.

An incidental use of this template, in conjunction with a DIAL INDICATOR, is for alignment testing, as shown in Fig. 12.21.

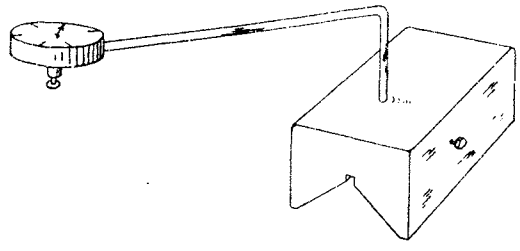


Fig. 12.21 Showing inverted V-template with attached DIAL INDICATOR.

Sec. 12.16
Limitations of the Small Hand Template

One special precaution should be observed when making a hand template to spot two mateing members, as shown in Fig. 12.22. The casting (A) is the stationary member and the casting (B) is the sliding member. It is essential that the 90° square edge way (W) have full area contact with the 90° square edge slide (S) when the two parts are finally placed together.

A template constructed to spot both of these surfaces must be exactly 90°. No tolerance can be permitted, otherwise area contact will be lacking. If the template varies even the slightest from a true 90°, and both the way (W) and the slide (S) are scraped to conform to it, a sloppy fit between the mateing parts is the inevitable result. Fig. 12.23 shows the condition which could develop. The contrast between (a) and (b) in the figure is deliberately exaggerated in order to clarify our imaginary case.

Still referring to the Fig. 12.23, it can be seen that the angular value transferred to both the Way (W) and the Slide (S) is identical, but in opposite directions. Consequently, when the members are placed in contact as in (c) the effect of the inherent error in the template will be doubled.

The better practice is to make the

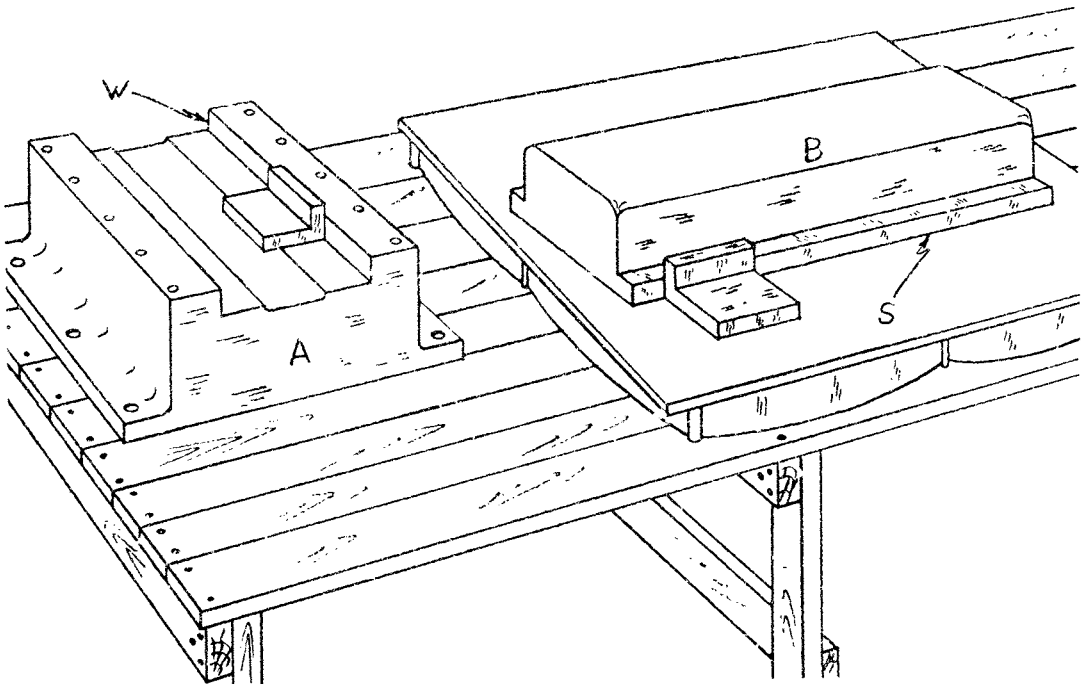


Fig. 12.22 Showing method of spotting a stationary way and mateing slide utilizing the same template.

template with precision but without an extravagant expenditure of time trying to attain perfection. Then apply it to either one or the other member as convenience suggests. After the selected member has been scrape-finished it should be used as a template for its mateing part. This procedure assures good fit and area contact, as represented at (d).

Sec. 12.17
Spotting Technique with Small Hand Templates

Small spotting templates which are useful in preserving definite angles and indicating high spots, must be employed with skill to render their maximum benefit. One obvious disadvantage is their smallness and consequent inability to indicate the overall flatness of the work surface. This can be compensated for by spotting alternately with a STRAIGHT EDGE, or SURFACE PLATE, of adequate size.

A second problem is non-uniform spotting which also derives from the small size of the templates. It is easy to see how this happens. If the template is coated with marking compound and then rubbed the full length of the work surface, the portion where the gage is first laid will be covered more thickly with the compound than the remaining area. This will be the case even should an attempt be made to equalize the distribution of the film by pushing the template back and forth several times from end to end of the work. Such an undertaking is generally ineffectual because the film is sticky and tends to adhere where originally deposited, and repeated movements only blur the markings. The portion of the work surface first spotted by the tool will invariably be most heavily coated. And a proportionately thinner film of medium will be applied to the areas farther from the point of first placement.

Ordinarily, on a rough or deeply worn surface, unequal applications of compound are not too serious because deep cutting is practiced when roughing out at the start of a job. In other words, the slightly inaccurate markings, resulting from variations in film thickness, are of no great consequence in the initial stages.

The real drawback of a small template is most noticeable when treating surfaces

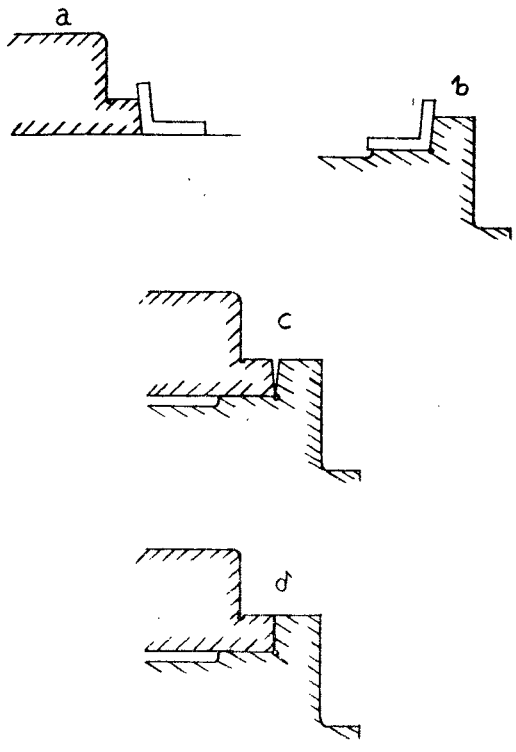


Fig. 12.23 Diagram of results of spotting with a template not precisely 90°.

(a) spotting a slide (b) spotting a way (c) showing line contact when members are assembled (d) showing area contact of properly fitted members

having a better bearing quality. On these, an unequal distribution of compound leads invariably to inaccurate markings which affect the judgment of the operator.

To handle the tool capably in such circumstances and to obtain accurate results, it is preferable to spread the marking compound on the work piece instead of on the tool. That is, the surface of the work is coated as thinly as desired. If bluing is used it is spread evenly by hand. In case Red Lead is utilized, it is similarly applied or it may be deposited by evaporation. (See Sec. 10.15). Then the clean template is rubbed across the coated surface of the work. This action strips away or discolors, the compound on the high spots thereby revealing their location. As an aftermath of each scraping cycle, the entire work surface must be cleaned of compound and metal chips. This, however, involves no additional labor because in the final stages of the job the surface is usually scraped over in its entirety anyway. By adopting the procedures outlined above, the precision and utility of small templates will be augmented.

Sec. 12.18
Utilizing Mateing Members as Templates

The reader, who has carefully studied the content of the preceding sections dealing with the construction of small hand templates, will have been impressed with the difficulty of the work. It is not the intention of the author to over-emphasize this phase of scraping. On the other hand, this subject was treated comprehensively because under some conditions small templates offer the only feasible method of performing a job.

These gages should never be made merely for the sake of making them. Frequently, standard spotting tools will serve the purpose just as well. The use of mateing members as templates should also receive earnest consideration because they offer an alternative method of spotting. A few remarks on the subject will be advisable.

There are three principal advantages in utilizing a machine member to spot its mate. First, it frequently eliminates the time and the effort required in making up a special spotting tool for a single time use. Second, spotting with a mateing member is the best assurance of area contact and good fit. Third, alignment testing is simplified in most cases, and as a result the incidence of error is reduced.

Ordinarily, when a machine member is to be used as a spotting tool for another member or part, it is first scraped to a bearing finish approximating SURFACE PLATE quality. This needs some qualification. We mean that the finish developed should approach this high quality only to the extent demanded of the job.

Slides are usually fitted to ways, though for convenience the opposite sequence is often used. One or the other set of bearings, after being scrape-finished, is used in the capacity of a template to spot its mateing member. Since the technique of spotting with bulky and heavy machine members is a tricky business it will be described in some detail in the following section.

After it has served its purpose as a spotting tool the template member may be deeply flaked, flowered or frosted to break up the relatively smooth bearing surface thereby providing oil pockets. While still being used for spotting purposes, a machine member acting as a template should never be decorated by frosting, etc. because such treatment would impair its quasi SURFACE PLATE quality.

Sec. 12.19
Spotting Technique with a Mateing Member

The proper methods of applying the SURFACE PLATE, STRAIGHT EDGE and the various small hand templates to the work have been discussed under their respective sections. The chief precaution to be taken with all these gages is to set them fully in place without sliding and to remove them in the same fashion.

Machine parts when used as templates to spot work surfaces require equivalent care. The utilization of one component to spot a mateing member is a frequently employed procedure in machine tool reconditioning. It is highly effective if properly applied but a source of false markings if incorrectly used.

The manner in which the actual physical contact takes place between the spotting tool and the work surface is a matter of supreme importance in obtaining accurate markings. We do not refer here to rough handling, bumping, etc., which is harmful at all times and places. Instead, we mean specifically the manipulation of the spotting gage or template so that there is no accidental contact of these tools with the work surface being spotted. Should this occur the markings will be blurred, modified or otherwise made inaccurate.

In discussing spotting procedures with mateing members, perhaps the principal thing to emphasize is that usually only one face of the template is used at a time. Thus each surface of the work piece is treated individually. Starting with the first surface, which is always a flat slide or flat way, as the case might be, the procedure is as follows:

Place the work surface in a horizontal position if possible. Apply marking medium to the spotting surface of the template member. Maneuver the template in mid-air until lined up properly, then seat with one movement. The usual spotting motion of short duration is performed, and the template is removed. This separation is as critical a procedure as the original placement. It must be done cleanly without any sliding. Otherwise, additional and consequently false markings will be formed. This routine is repeated as often as necessary until the first surface of the work piece has been scrape-finished. The smooth finished plane can now be used as a rest or support for the template while the next bearing i.e. an adjacent guiding way or guided slide is spotted.

For this phase the template is laid on the surface first scraped (which is lightly oiled to prevent scoring.) Then by pulling or pushing, as required, the template is seated in one direct movement against the second surface to be spotted. After the marking compound has been transferred, the members must be cleanly separated.

For a practical example of this procedure the routine of spotting the slides or under surfaces of the saddle of the horizontal milling machine, described in Sec. 27.52, should be studied.

In this example, we will use the flat way of the knee as a template, first coating it with marking medium. Then the saddle is maneuvered over the knee until correctly lined up. Next it is required to make full and complete contact in one movement. After spotting is completed, the saddle is separated abruptly. This procedure is repeated time after time until the saddle flat slide is judged to be adequately scrape-finished.

We will now use the guiding way of the knee as a template, first coating it with marking medium. The next step is to fit the guided slide of the saddle to it. This is done by resting the saddle flat slide on the lightly oiled flat way of knee meanwhile keeping the guided slide from making any contact with the coated surface. When it is correctly positioned, the saddle guided slide is pulled against the knee guiding way, making full contact with one pull. Separation of these surfaces is in like fashion. In short, disengagement must be immediate and complete with one movement to avoid false markings.

In summary, we can say that the

surfaces should make a complete overall contact instantaneouly. If one member is carelessly slid into position against the other, false markings are inevitable. While transferring the marking compound, firm pressure is applied to keep both surfaces in full contact for the duration of the spotting movement. Then the template surface is cleanly separated from the work surface.

This practice of using a mating member as a template is especially appropriate when spotting dovetails. At best, it is not easy to spot them properly, but the method above outlined will minimize the difficulty.

Chapter 13

SQUARES

In scraping work the SQUARE is used for checking the alignment of axes and surfaces. Applications in common usage will be described.

Sec. 13.1
Kinds of Squares

Squares are classified in several general forms enumerated as follows:

1. The TRY SQUARE or hardened solid steel square.

   This type represented in Fig. 13.1 is not graduated. It has a thin blade from 6" to 26" long. The length of the beam ranges from a few inches to about 20". Accuracy standards are (±) .00025"per foot.

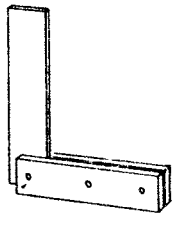


Fig. 13.1 Try Square or hardened solid steel square.

2. The BOX SQUARE

   The box-section form shown in Fig. 13.2 is generally made of cast iron with the faces scraped square.

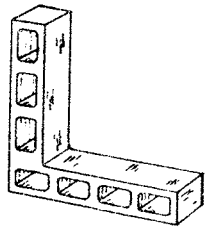


Fig. 13.2 Box Square.

   Accuracy should be (±) .00025" per foot. This tool is most frequently used in conjunction with a DIAL INDICATOR

3. The SCRAPED TRIANGLE

   Fig. 13.3 shows the Scraped Triangle. It is made from cast iron with two scraped faces 90° apart. It is employed principally for testing final alignments.

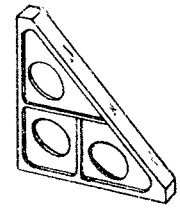


Fig. 13.3 Scraped Triangle.

4. CYLINDRICAL SQUARE

   This form is made of steel, hardened and ground parallel from end to end. (See Fig. 13.4) The end faces are ground square to the cylindrical portion. Ordinarily, this type is used for checking purposes in the inspection department and not by the scraper for alignment tests. When used in conjunction with a flat surface it will check a 4" piece within 00° 00' 15" of an arc. The sizes commonly used range between 4" to 10" in height and between 2" to 3" in diameter.

Fig. 13.4 Cylindrical Square.

Sec. 13.2
The Try Square

The TRY SQUARE, known variously as the hardened solid steel square, MASTER SQUARE, etc., is shown in Fig. 13.1. It is found in most machine shops where it is used regularly for many purposes. For example, it is utilized in laying out and setting up work; for checking machined surfaces; and more relevant to the scraper, for alignment testing.

For some applications the TRY SQUARE is not as suitable as either the SCRAPED TRIANGLE or the BOX SQUARE. However, one of the aims of this book is to demonstrate how equipment usually found in the average shop can be efficiently employed. Therefore, from time to time, this tool will be incorporated in a number of practical set ups. For such work the TRY SQUARE should be adequate in size and in perfect condition.

The blade of the TRY SQUARE is relatively thin and hence semi-flexible. Since it is subject to bending, considerable care must be exercised when using it while testing alignments.

The tool is applied by the scraper in a number of different ways, including the following:

1. Sighting
2. Tapping with the fingers
3. Testing with feeler gages
4. Testing with a DIAL INDICATOR

Each of these applications will be discussed in the order enumerated above.

Sec. 13.3
Sighting a TRY SQUARE

Sighting a TRY SQUARE is a method of checking the flatness of a surface or its squareness with respect to another surface. The operation consists of laying the beam of the SQUARE on a surface and butting the blade against another surface situated at 90° to the first. The operator sights between the blade and the adjacent surface towards the source of a bright light, such as a window. Since this is a very common practice in machinist work and familiar to all mechanics, it need not be further described. Within limits it is a qualified test, therefore the following criticism is not meant to under-rate its practicality in its proper field.

Despite its wide acceptance in the machine trade, the scraper does not find sighting with a SQUARE either an efficient or accurate test when he tries to check a scraping alignment. In the first place, the kind of finish has a considerable influence on the reliability of visual testing. A ground surface, for example, being smoother is checked somewhat more accurately by this method than one that is in process of being scrape-finished.

Another objection is that the kind of work pieces usually scraped by hand are generally too large or too heavy to lift or otherwise shift around with facility. Then too, the window frequently is not in line with the work surface being tested.

To overcome this obstacle artificial illumination is sometimes resorted to. However, an ordinary electric lamp drop cord assembly is usually unsatisfactory because the light must be visible at one time along the entire area being sighted. From a stationary position the illumination provided by the lamp is insufficient to range uniformly over the full length of the bearing being checked. While it would be possible to move it along, as the operator scans the space between blade and work, this is ineffectual due to the inability of the retina to compare present with past images.

Over short lengths, the average eye is quite efficient at determining parallelism, or divergence therefrom. However, as the distance increases to a point where the eye cannot take in the complete picture at one glance, its dependability declines. Moreover, it is not capable of estimating the amount of such deviation, which information is so necessary for most alignments. The scraping operator is frequently confronted with situations wherein he must know the degree of error and not merely be aware of the direction such divergence takes.

The reason that the deficiencies of this method have been stressed is that sighting a TRY SQUARE is an accepted test and standard procedure in machine shop practice and for that reason might erroneously be assumed to be equally appropriate for checking scraping alignments. From the

explanation given it will be seen this is not the case.

Sec. 13.4
Tapping the TRY SQUARE

In the preceding section we have shown that under most conditions it is inadvisable to attempt to judge the alignment of the scraped surface by butting a SQUARE against it and sighting between. For scraping requirements this procedure will not be precise enough after the surfaces are scraped nearly square.

A better practice, which may be easily applied, is called tapping the SQUARE. After butting the blade against the surface being tested, the top of the blade is tapped gently with the fingers. By noting the drag or its absence, as the blade sways sidewise, it is possible to determine the relationship of the surface to the tool. In other words, the reaction to the tapping tells whether the tested surface is square with the beam of the TRY SQUARE, and if not, in which direction the misalignment is. Experienced scrapers are able to estimate closely the amount of deviation; for the novice the following method is recommended.

Sec. 13.5
Testing with FEELER GAGES on surfaces which are nearly square.

This method of determining whether two surfaces are square is one that scrapers frequently employ. Not only does it indicate the lack of squareness and the direction of the error but also its approximate scope. To employ it, for example, in testing the relationship of a vertical surface to a horizontal surface, the TRY SQUARE is set upright, the beam resting on the horizontal plane. Two pieces of feeler stock of equal thickness are held against the vertical test surface. They should be as widely separated from each other as circumstances permit. Then the blade of the SQUARE is brought up against the feeler stock so that it barely touches.

Just enough pressure is applied so that a slight drag is felt as the feeler stock is pulled out from under the blade. The feeler stock is withdrawn in 1/4" steps by pulling on each piece alternately. By the time the feelers have been totally removed, a definite opinion will have been formed of the comparative pull necessary. If the effort required is equal, the surfaces are square. When one feeler can be drawn out more easily than the other, it is evident the surfaces are not square and further indicates the direction of the error.

This test is very accurate when performed by a mechanic with a delicate sense of touch. However, even the average workman is able to detect a variation of a few tenths of thousandths. The feeler test is far superior to any calibration relying solely on visual inspection. The acquisition of a sense of touch is the reward of practice and experience. Naturally, this ability is not cultivated in a day.

A word about handling the square when employing feeler stock is advisable. For the average person best results will be had by manipulating the SQUARE with the left hand grasping the beam. Heavy pressure should not be applied to the beam nor should the SQUARE be rammed tightly against the test surface. It is so easy to cock or bend the blade of the SQUARE that, unless definite restraint is exercised, serious errors in testing alignments for squareness between surfaces will inevitably occur. The left hand must exert a medium pressure on the beam of the SQUARE. It should be only enough to move the tool steadily and without hesitation into position. At the moment of contact further pressure must cease instantly. It is definitely good practice to withdraw and advance the tool into position several times to obtain just the right contact pressure before any attempt is made to withdraw the feeler stock. The sense of touch in manipulating the SQUARE is of equal if not greater importance than that required to sense the "drag" of the feeler stock.

Sec. 13.6
Alternative Methods of testing with Feelers.

There is an alternative method of utilizing the TRY SQUARE and feelers whereby it is possible to measure closely the degree of variation from squareness, when checking the alignment of one surface with another. It requires the use of feelers of different thicknesses. By substituting various calipers, feelers are finally

selected that exhibit an equal resistance or drag when pulled. The difference in their thickness represents the misalignment.

When applying this method the preferred practice is for two men to work together. While an assistant holds one feeler against the test surface, near either the top or bottom of the blade, the mechanic manipulates the other feeler. This arrangement permits the mechanic to use his free hand to buck the SQUARE against the feeler stock with the required steady pressure.

It is also entirely practicable for one mechanic to work by himself. He should proceed as follows:

A few drops of oil are spread on the surface being tested at the point where one of the pieces of feeler stock will be placed. Then a single piece of feeler stock about 2" long is "glued" there. The oil film will prevent it from falling. With this arrangement the blade of the TRY SQUARE can be properly butted against the feeler stock with one hand while the other hand is free to make selections and to manipulate the second piece of feeler stock to determine the amount of plus or minus.

There is nothing haphazard about where to locate the thinner of the two feeler gages. If, for example, it is reasoned that the top of the vertical test surface inclines away from the blade of the tool, the thinner feeler is positioned near the bottom. On the other hand, if it is thought the bottom is open wider, the thinner feeler is held against the vertical work surface, at the top of the SQUARE. Under both conditions the second or thicker feeler is placed at the end opposite.

When both feelers have an equal "drag" or tightness they are correctly sized. The value of the thin feeler is subtracted from the caliper of the thick one, and the difference represents the amount the surface is out of square. When the feelers are of equal value, it denotes an exact 90° alignment.

Sec. 13.7
Hints on using TRY SQUARE and FEELERS

Skill in manipulating the TRY SQUARE and feelers comes only with practice, but in lieu of experience, a few pointers will be helpful.

1. To judge the suitability of the selection, partially withdraw, in alternate steps, first one piece of feeler stock from between the test surface and the SQUARE, then the other piece. From the drag felt, the operator is able to judge whether the correct thickness has been chosen. When an equal pull is required to withdraw both feelers, the proper sizes have been inserted.

2. Under no circumstances should the operator attempt to insert various sizes of feeler stock at one end of the blade while the opposite end is bucked against another piece of feeler stock held next to the test surface. Such a course can lead only to erroneous results. This is especially true if the feeler stock is being inserted at the tip of the blade, where the lateral movement may be considerable.

3. A feeler should never be inserted when the TRY SQUARE is bucked directly against the test surface. It is virtually impossible to gage correctly in this way. When attempted, errors of two to six thousandths of an inch are common. One reason for this is the operator's inability to hold the SQUARE with just the right tension against the test surface while simultaneously inserting the feeler. Complicating the operation further is the extreme flexibility of the feeler stock, especially in the thinner gages. In short, two feelers should always be used and the blade advanced to touch them.

4. Always work with the thinnest feeler stock available because any error in gaging is magnified as their thickness increases. Since two pieces of stock are required for a test, it is advisable always to select a .0015" caliper as the thin feeler. Then choose progressively thicker pieces until the proper one is found.

5. For accurate results, and in scraping, precision alignments are of paramount importance, the feelers are held next to the test surface and the TRY SQUARE is butted against them. This procedure is repeated until the proper feelers are selected and proved correct by their equal tightness between the test surface and the tool.

6. The use of a Thickness Gage consisting of leaves of progressive caliper is not recommended for alignment work where extreme accuracy is required, as for example, on machine tools. These operations are usually conducted with a

SQUARE centrally positioned on the bearing surface and thus more or less removed from the edge. Consequently, due to the design of the Thickness Gage, inserting one of the leaves would necessitate bending it in a curve. Part of this bending pressure may react against the SQUARE, forcing it sidewise or away from the test surface. This effect is especially noticeable when manipulating the thicker and less flexible leaves. The bending tension of the leaf affects the nicely applied pressure which must be exerted on the TRY SQUARE before it is considered properly "butted". More accurate results will always be realized when individual pieces of feeler stock are used instead of Thickness Gages.

Sec. 13.8
Testing with a TRY SQUARE and a DIAL INDICATOR

In lieu of feeler gages a DIAL INDICATOR is often used in conjunction with a TRY SQUARE to ascertain whether one surface is square with another. Performing this operation is quite difficult because the blade of the SQUARE is both thin and flexible. Consequently, the accuracy is never equal to that possible with a SCRAPED TRIANGLE. Much can be done though to counteract this flexibility, For example, when the tool is in the horizontal position, one simple plan is to support the end of the blade with a metal block of suitable size. Fig. 28.30a shows how such an arrangement can be applied when checking whether the flat ways of the milling machine knee are square with the guiding way of the milling machine column. This expedient will hold the blade steady and unbending at the point where the button of the DIAL touches it.

Another way to enhance the reliability of the test is to position the button of the DIAL INDICATOR exactly on the center line of the blade's thin, flat edge. This precaution permits a small movement to either side without riding off the edge. It compensates to some extent for any displacement should the test surface diverge from the blade or the blade bend due to its position. With the wide edge of of a SCRAPED TRIANGLE or BOX SQUARE such problems would not occur and hence readings are more accurate with these tools.

Chapter 14

LEVELS AND LEVELING

The type of LEVEL discussed in this chapter is a precision instrument. As such it requires skill in handling to derive the maximum accuracy in readings. Familiarity with the LEVEL will assist the operator in reconditioning machine tools and, furthermore, aid in maintaining these tools in good operating order.

The importance of accurate instruments and the expert use of them cannot be overemphasized. The accuracy and quality of finish of present day production depends to an important degree on the levelness of the machine tool. Too many machines are prematurely condemned to the scrap heap when the principal fault is improper leveling. Negligence in this respect leads to the rapid deterioration of even the sturdiest machines, and it is an important item of shop and factory expense.

All machinery should be checked for levelness at regular intervals and releveled if necessary. It is essential to do this frequently because the shims driven under the bed of the machine may deteriorate or shift their position. There is also a tendency in some buildings for floors to sag. These influences cause the machine to warp. When a "wind" is present in the ways, correct alignment is lost and there is a proportionate deterioration in accuracy of work and quality of finish.

Sec. 14.1
The Level

The LEVEL is a tool which determines the deviation from the horizontal plane. It consists of a glass tube having a slight internal curvature. The vial is nearly filled with a volatile fluid such as ether. When the ends of the vial are hermetically sealed, the air within forms a bubble and becomes the indicator. Lines are scribed on the glass tube, as represented in Fig. 14.1. It is the position of the bubble with reference to the graduations which indicates deviation from the horizontal plane.

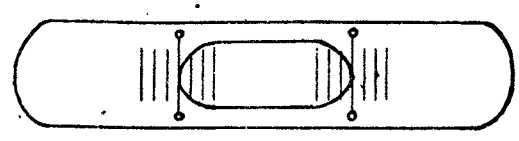


Fig. 14.1 Diagram of glass vial of PRECISION LEVEL showing graduations.

The vial is contained within a brass tube. In the cheaper LEVELS the vial is held with plaster-of-paris at both ends. With the more sensitive instruments the vial is secured at one end only by plaster-of-paris, and the other end is supported with cork. The brass tube is mounted in a suitable frame having a flat base. The base is pin point hand scraped and sometimes is provided with a longitudinal groove. The groove, which may be either concave or a V, is aligned with the base. The groove simplifies levelling operations when the instrument is laid on a cylinder.

Two general classifications of PRECISION LEVELS are seen in scraping operations. The horizontal type is the most common, but the special form known as the Frame Type is also used.

Some instruments are very sensitive to even slight changes in position and others require an appreciable displacement before the movement of the bubble is noticeable. The MASTER PRECISION LEVELS, which are the only kind suitable for scraping work, have a sensitivity of at least 0.0005 to 0.00075 inch per foot.

Sec. 14.2
Sensitivity of the Level

The sensitivity of a LEVEL, that is, its ability to indicate changes in position is dependent entirely upon the form of the inside surface of the glass vial. The

cheaper LEVELS have vials which are straight pieces of glass tubing bent to a slight curve. This type will not be discussed as it is of no value to the scraper. The other kind, known as a PRECISION LEVEL, has a glass tube whose inside is ground to a barrel shape, that is, slightly concave. The greater the radius of curvature of the inside surface of the glass, the more responsive the instrument to changes in position.

0.000125 inch per foot. This data is very pertinent to scraping operations because properly selected tools are essential to accurate work.

For precision alignments of machine tools, the LEVEL should have a sensitivity of about 0.0005 to 0.00075 inch per foot for each graduation. Anything in excess of this is not practical for the average shop because the vibration of machinery will not permit the bubble to

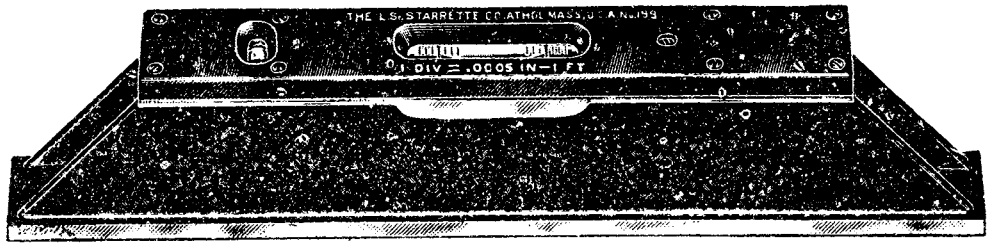


PLATE 12. Master Precision Level. Accuracy - 1 division equals 0005" - 1 ft. (Courtesy - L. S. Starrett Company, "World's Greatest Toolmakers" Athol, Mass.)

Thus in Fig. 14.2, the radius of the curvature (R) of the inside surface of the glass, determines the sensitivity. Radius is indicated in Feet. The distance between each graduation on the vial is known as a division and is usually equal to .050 or .100 of an inch.

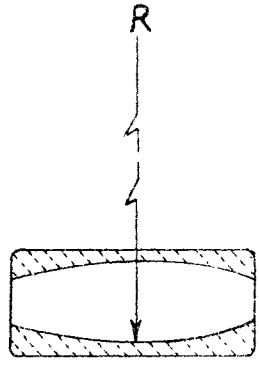


Fig. 14.2 Horizontal section of glass vial showing concave curvature.

(R) radius of curvature

It is comparatively easy to estimate to within 1/4 of a division because the quarter divisions are directly proportional. Thus with a LEVEL of ten second sensitivity, one division is equal to 0.0005 inch per foot and a quarter division is equal to

come to rest. On the other hand, an instrument below that standard is not satisfactory because it is difficult to judge small fractions of a division. The sensitivity of the instrument should always be commensurate with the standard of precision of the machine being measured.

The operator should know the sensitivity of his LEVEL in order to work intelligently. This information is indicated on the instrument by some of the manufacturers. When not given, this data may be obtained from the maker.

While the length of the bearing surface of a PRECISION LEVEL has nothing to do with sensitivity, nonetheless, the longer base can measure between points farther apart, which often is an advantage. For application to the average medium size machine tool, the length of a spirit LEVEL should be between 8" and 15". To increase its effective length, a SCRAPED PARALLEL can be placed underneath as a bridge.

Sec. 14.3
Testing the Precision Level for accuracy.

When the PRECISION LEVEL is first purchased it has already been checked for accuracy. Factory inspection is most thorough and the possible error would be less than 1/4 of a division which can be

ignored. After being placed in shop use the tool should be tested at frequent intervals and adjustments made when necessary. Tests are best carried out in the inspection department where room temperature (68° F.) is maintained. Allowing the LEVEL to reach this temperature before commencing a test, or before scraping or adjusting it in any way, is good practice.

To check the tool proceed as follows:

1. The base of the instrument is spotted on a SURFACE PLATE using as a medium either Red Lead or alcohol deposited by evaporation. If flatness is indicated, the second step can be taken immediately. However, in case dent burrs or a warp is evident in the base, it must be scraped till flat. In doing this take care not to warp the base further by improper clamping methods. When a flat condition is achieved, the bubble is adjusted to the scrape-finished base, as described in the next test.
2. The LEVEL is placed on a SURFACE PLATE which previously was leveled by an instrument of known accuracy. The bubble in the LEVEL being checked must center. If this condition is observed the instrument is reversed by 180° and another observation made. Perfect accuracy is indicated if there is no change in the position of the bubble. When a shift of more than (+) 0.25 of a scale division in either direction is noted, the vial should be adjusted within this tolerance.

In case the operator doesn't have a second LEVEL of proven accuracy, the test can be performed if the SURFACE PLATE is made approximately horizontal. The LEVEL being checked is then placed on the PLATE and a line is traced around it. After noting the position of the bubble, the gage is reversed 180° and set within the penciled outline. If the bubble moves in the same direction and an equal number of divisions as before, the LEVEL is accurate. Otherwise, the alignment of the vial with the base is faulty.

Sec. 14.4
Testing Precision Levels having V grooves

When a groove is incorporated in the flat base of a PRECISION LEVEL it introduces an additional factor in the alignment of the instrument. In addition to scraping the base flat and aligning the vial to it, as we explained above, we must now align the groove to the base.

On some PRECISION LEVELS the groove is in the form of a V. On others, it is circular, usually a segment of a 1" circle. Since there are some differences in reconditioning and testing the alignment of each type of groove, they will be discussed separately.

When checking a V-groove, the apparatus required consists of several hardened and ground PRECISION CYLINDERS having diameters progressively sized and small enough to permit them to enter the V-groove. These cylinders are employed to check the surface of the groove, in so far as it is practicable, by line contacts.

The test is executed by laying a PRECISION CYLINDER on top of a SURFACE PLATE which has been adjusted exactly horizontal. Next the LEVEL being checked is set on the CYLINDER in such a way that the cross-level is centered. We now observe the large bubble which should be centered if the V-groove is properly aligned to the flat base. For double assurance, the test is repeated with several sizes of CYLINDERS. In all cases the bubble must center to indicate that the V-groove is properly aligned to the base. If a discrepancy is apparent, it can be corrected by scraping the V-groove. A small STRAIGHT EDGE will be handy for spotting purposes.

Sec. 14.5
Testing Precision Levels having circular grooves

When checking the alignment of a circular groove with the base of a PRECISION LEVEL, a hardened, ground PRECISION CYLINDER is used. The diameter of the CYLINDER must match the groove. To make the test the CYLINDER is set on

the SURFACE PLATE, and the PRECISION LEVEL is placed on the CYLINDER. The instrument is held so that the cross-level is centered. If the bubble in the large vial is also centered, the groove is accurately aligned in the vertical plane with the flat base. Any indicated error is rectified by treating the groove, not the base. In this operation, spotting is done with the same CYLINDER used in the test. After a film of Red Lead or alcohol is deposited by evaporation in the groove of the LEVEL, the CYLINDER is applied to test for bearing quality. The scraping procedure is similar to that of scraping-in a round bearing.

Sec. 14.6
Causes of incorrect readings with a Precision Level

Accurate results can be obtained with a PRECISION LEVEL only if proper methods are used. Inexperienced operators, particularly, are often puzzled by unstable readings and are at a loss for a reason. The fault in most cases can be traced to one or more of the following factors, viz:

1. Condition of the surface being tested.

   The bubble will register its position only in reference to the base of the LEVEL. If the base is not resting on a smooth surface, obviously the bubble will not truly indicate the condition of the surface. Thus the surface being checked should always be spotted to make certain that it has no burrs. Loose grit or chips can cause trouble also.

2. Improper manipulation

   When reading the LEVEL both eyes should be open and the operator should look in a direction perpendicular to the bubble in the vial, the latter to prevent parallax. The cross-level will facilitate correct measuring especially in testing inclined surfaces. If this is lacking, the measuring direction must be adjusted by trial and error.

   It must be remembered, too, that the indication of the bubble refers only to a straight line in the direction of measuring. Thus it is a line measuring device. When planes are to be tested, the LEVEL must be placed in two positions at right angles to each other.

3. Temperature variations

   The PRECISION LEVEL is very sensitive to temperature changes whether due to sunlight, drafts of air, breathing on the vial or touching with the hands. All will lead to faulty indications. By suitable precautions, disturbances due to such causes can be practically eliminated.

4. Placement of the instrument

   Improper placement of the PRECISION LEVEL when measuring the straightness of a way can result in error even though the bubble centers. To assure accuracy the bearing base of the instrument must always be parallel with the axis of the way. With flat ways this is a simple matter of laying the instrument longitudinally on the surface and lining it up. A V-way or inverted V-way, on the other hand, can be tested for straightness only by interposing a PRECISION CYLINDER or an inverted V-gage between the bearing and the LEVEL. Thus the LEVEL is aligned to the axis of the way automatically and exactly.

Sec. 14.7
Leveling Applications

Leveling, as it is treated in this book, is essentially two distinct operations.

First, there is leveling that attends the erection of a machine tool on a factory floor. There is no difference in the method of doing this as between a new machine direct from the manufacturer and a machine newly reconditioned. The process should be familiar to most readers because the subject has been adequately treated in numerous books on machine shop practice, as well as in manufacturer's manuals. If anything needs to be repeated here it is the recommendation to utilize a PRECISION LEVEL of high sensitivity, at least equal to the tolerances it must check.

The chief obstacle to overcome is a sagging floor. Even the most strongly trussed machine tool cannot surmount such a handicap and continue indefinitely to produce work of dimensional accuracy and quality finish. This is to say nothing of the detrimental effect on the bearing surfaces of the slides and ways. On such a floor, leveling tests must be performed very frequently, or risk serious damage to the machine.

Second, is the technique of leveling the main casting, prior to rescraping a machine. Here we touch upon the question of reworking the leveling surfaces and related matters. This aspect of leveling should be thoroughly understood by the scraper engaged in machine tool reconditioning because it is the fundamental operation.

Closely allied with this is the execution of alignment tests during routine scraping operations. For example, the PRECISION LEVEL may be used to keep one surface parallel with another. Speaking generally, it is applicable to such operations when conditions are unsuitable for the employment of a DIAL INDICATOR, the gage ordinarily used. This might be the case when one surface is too distant from the other. Then an attempt to use the DIAL INDICATOR by spanning across with a long extension rod, will automatically introduce errors in excess of the tolerance allowed. This would be due to the flimsy set up normally utilized.

To cope with this situation, the distance can often be bridged with a SCRAPED PARALLEL. The PRECISION LEVEL is placed upon it, and the check made. Errors attributed to unsubstantial set ups are thus eliminated. Fig. 25.35 shows such an application.

Sec. 14.8
Leveling Surfaces on Machine Tools

Leveling can be conducted only from a leveling surface. This is a plane incorporated in the design of a machine and used as a base on which to set the PRECISION LEVEL. Familiarity with the construction and function of machine tools is essential to locate the leveling surfaces. On some machines the work surface is the leveling surface, as for example the top of the table on a horizontal or vertical milling machine. Sometimes the bearing ways are utilized for leveling. Typical of this are the bed ways of the planer or the lathe. Frequently, the maker provides surfaces intended specifically for leveling, such as the top finished surfaces on large grinding machines.

Sec. 14.9
The Importance of Leveling the Main Casting.

Immediately after dismantling a machine tool, and preparatory to rescraping it, the bed, frame or casting, as it is variously called, should be leveled. The purpose of the leveling operation is to distribute the weight of the machine bed to match the distribution that was established at the original scraping-in operation at the factory.

The importance of leveling this member cannot be overemphasized. This procedure should always be performed from the leveling surfaces and in both directions, longitudinal and transverse. When the leveling surfaces are in good condition, the original plane may be very closely duplicated, otherwise, only an approximation is possible. Naturally, the more accurately the job is performed the less "wind" remains to be scraped out of the bearing ways.

The necessity for precision leveling increases with the length of the bed. A short, compact, main casting is comparatively rigid and less subject to "wind" in the bearing ways, than a long frame. For example, the milling machine and shaper are less critical from that standpoint than a planer, grinder or lathe which have notably long beds.

If the bearing ways were to be rescraped to a correct alignment without first leveling the bed, or main casting, there would be two unfortunate consequences:

1. Due to a "wind" in the bearing surfaces, (all unleveled castings have a twist) more metal must be removed than would be required if the bed were first leveled to its original factory plane.
2. As a result of the twist in the ways of the bed, they are less suitable as patterns in the preparation of mateing

members as spotting templates. For example, in rescraping a lathe, the bed ways even in their worn condition can be used in this capacity. From the standpoint of greater accuracy it is advantageous, therefore, to eliminate from the ways as many errors as possible of which "wind" is the most serious.

Sec. 14.10
Technique of Leveling a main casting to the Original Plane.

This operation is begun by laying a PRECISION LEVEL on the leveling surfaces of the machine tool. Incidentally, make sure that these surfaces, as well as the base of the instrument itself, are clean. The instrument is laid successively both lengthwise and cross-wise. Meanwhile, the leveling screws ranged along the base of the casting are adjusted slowly and evenly until the bubble in the vial indicates absolute levelness with the instrument set both ways in turn. When this condition is achieved, the bed is correctly leveled. (Machines not provided with leveling screws will require the driving of tapered steel wedges or shims under the base to equalize the uneveness of a floor.)

Sometimes a machine bed is so badly worn or abused that leveling it becomes a major problem. The leveling surfaces on which the LEVEL should be set may be damaged or warped thereby casting suspicion on the reliability of the readings. Under these trying circumstances the approved procedure is as follows:

1. All burrs should be carefully removed from the leveling surfaces prior to using a PRECISION LEVEL. A STRAIGHT EDGE or SURFACE PLATE will reveal these projections which can be filed or scraped away.
2. The machine is then leveled to the original factory plane. By this we mean that the bed casting is adjusted so that the bubble centers as closely as possible after laying the instrument in many different positions. While doing this we also take into consideration the indicated wear if a bearing surface is being used as a leveling surface. A permanent warp in the casting will, of course, prevent any exact leveling, therefore, an average calibration of many locations is taken as the selected reading and the machine so adjusted.
3. After the machine bed is leveled as closely as practicable, the leveling surfaces should now be scraped flat. This condition is deemed fulfilled when a PRECISION LEVEL set anywhere on them will indicate dead level.
4. When this is completed the rescraping of the bearing ways of the bed may be commenced. Occasionally a PRECISION LEVEL is placed on the leveling surfaces to indicate whether the casting is shifting position during the scraping of the ways.

Sec. 14.11
Use of the Level as an aid to scraping "straight down".

Essential in the reconditioning process is the practice of scraping "straight down." The necessity for such procedure is dealt with elsewhere, and we are now interested primarily in the part that the PRECISION LEVEL plays in the manipulative procedure. In short, the PRECISION LEVEL is used as a continuing check concurrent with the removal of metal from the work surface of a given member. While this is an accessory application of the PRECISION LEVEL, it is, nonetheless, of considerable importance.

Briefly, the technique is to set the instrument, at the conclusion of each scraping cycle, on the surface being scraped. The position of the bubble will guide the operator in scraping "straight down" at the succeeding cycle, and so on.

When the PRECISION LEVEL is used as mentioned above, it is absolutely essential to block the work piece solidly after leveling it, preparatory to scraping. This is necessary so that the casting does not shift, slip, or otherwise change position during scraping operations.

A little thought will reveal the reason for this precaution. The location of the PRECISION LEVEL during preliminary leveling operations would, naturally, be on the portion of the work surface least affected by wear. By using this remnant of the original surface, a closer approximation to accuracy is possible. However,

this portion of the original surface must also be scraped. In fact, it is the part that will have the most metal removed because, in the first place, we must lower the surface to a plane parallel with the original factory new surface; i.e., scrape "straight down." And secondly, this new plane will be but very little beneath the most worn portion of the bearing surface but may be quite far beneath the relatively unworn portion of the surface on which we first laid our LEVEL. Therefore, unless the casting is kept immobile after it has been leveled, our ability to replace it in the original plane is practically nil because the last trace of the original surface will have been scraped away during the initial scraping cycle. After it is destroyed, any attempt at releveling in the original plane amounts to guess work.

Failure to block the work piece solidly is the cause of much trouble for the neglectful operator. Additional information on this subject is given in Sec. 28.10 on Vertical Mill.

QUESTIONS and ANSWERS

Sec. 14.12

Q. Who decides how the main casting of a machine tool is to be adjusted so that it is considered level?

A. This matter is determined by the manufacturer who provides top finished surfaces, or leveling surfaces, on the main casting.

Sec. 14.13

Q. What is a leveling surface?

A. It is a flat area on which to place a PRECISION LEVEL when leveling a casting.

Sec. 14.14

Q. What is the function of a leveling surface?

A. It is introduced into the design to provide the maker with a Datum Plane for the scraping-in of the bed casting. It is equally useful to the scraper who reconditions the casting. The ultimate user is also benefited because leveling surfaces make possible the accurate adjustment of the machine to exactly the same position it occupied when it was scrape-finished at the factory.

Sec. 14.15

Q. Is it always necessary to level a machine before rescraping it?

A. Theoretically speaking, if a machine were to remain in exactly the same position and place where it was rescraped and aligned, there would be no necessity to level it. This, however, is an impractical supposition as all machines shift their ground for one reason or another, not to mention that they are frequently moved to new locations. When the alignment or relation of the members to each other changes, inaccuracy results, and there is an immediate and noticeable deterioration in the dimensional accuracy of output as well as the quality of finish.

Sec. 14.16

Q. Why is it necessary to provide leveling surfaces?

A. To cite one reason, if the foundation settles the machine becomes misaligned, thereby causing inaccurate work to be produced. In a lathe, for example, "wind" may develop. This condition is revealed when the machine will no longer bore a straight hole. It is necessary, therefore, to have some method whereby the machine may be restored to its original position; hence, leveling surfaces are provided.

Sec. 14.17

Q. Why is it so important to level a machine tool preparatory to rescraping it?

A. It is essential to level a machine before scraping for just one reason; namely, to remove any warping. No matter how well designed and ruggedly constructed the bed, frame or base of a machine may be, it is subject to strains. Therefore, to remove distortions and warping, which further impair whatever accuracy the machine may still possess, it should be leveled.

Sec. 14.18

Q. Why is it desirable to level a machine tool to its original or factory-new position before rescraping it?

A. When a machine is leveled to its original or factory-new position, prior to rescraping, all pressures and distortions, due to imbalance, are eliminated from the bearing surfaces. As a consequence, the bearing ways are not in a warped position, thus less metal need be scraped from them to restore the correct alignment. Furthermore, the displacement of gearing, shafts, etc. will be held to a minimum.

Sec. 14.19

Q. How can leveling surfaces which are worn be used to level a machine tool?

A. The leveling surfaces should be used to adjust the machine tool as nearly as possible to dead level. Not infrequently the leveling surfaces are so badly damaged that only a close approximation to the original plane of the machine may be obtained. This close approximation is all that is immediately necessary. Since the new position assumed by the machine becomes the basis for all future re-leveling, the leveling surfaces should be reconditioned so that a PRECISION LEVEL placed upon them will register dead level. This must be done before dealing with the bearing surfaces.

Sec. 14.20

Q. Why should the leveling surfaces be dead level before commencing to scrape the ways of the main casting?

A. Before undertaking to answer this question it will be conceded that the ways of a bed can be scraped to accurate alignment even if dead level is not used as a Datum Point. However, it is a risky business for the operator to begin scraping the ways of the bed before the bubble in the glass vial of the instrument is centered, i.e. dead level without tolerance. In the first place, the casting may shift position during the scraping process. Should this occur it can be releveled only by guess which, quite understandably, is not favored for precision work. But the more serious difficulty is encountered later when the finished machine is erected for use elsewhere, for then it becomes almost impossible to keep in mind what tolerance was allowed and in which direction. In other words, the question confronting the erector will be "How far from dead level shall the machine be set when it is installed in its assigned place on the factory floor?" Remember, it is essential that a machine be erected in the same plane as that in which it was scraped, in order to retain the accuracy of alignment. Otherwise, the machine is seriously deformed by any new distribution of the weights of the various heavy sub-assemblies. If dead level is used as a Datum Point, there is little or no liklihood that experienced mechanics will mistake instructions.

Sec. 14.21

Q. Can the leveling surfaces be ignored during a rescraping operation?

A. No, the leveling surfaces cannot be disregarded under any conceivable set of circumstances. If not in good condition at the start, they must be treated until they are. This may require their modification by filing or scraping, Treatment of the leveling surfaces is continued until a PRECISION LEVEL can be placed on them and read dead level in both directions. The value of this practice is that at any time thereafter, the machine can be easily re-leveled if for any reason it shifts position. In other words, the condition of the leveling surfaces should be the first concern of the operator before any rescraping operations are begun on the ways of the bed.

Sec. 14.22

Q. When should the leveling surfaces be modified?

A. It is good scraping practice to modify these leveling surfaces immediately after the leveling process, i.e. after leveling the bed. They should be spotted with a STRAIGHT EDGE and/or SURFACE PLATE and then filed or scraped until their condition is such that a PRECISION LEVEL placed in any position on them will check dead level. This precautionary measure should be performed before undertaking to scrape the ways of the

main casting. The advisability of this course can be better appreciated by the novice after becoming familiar with conditions. For instance, scraping operations on a certain job are sometimes suspended for days at a time due to pressure of more urgent work. Upon return to the scraping job, a LEVEL placed on the leveling surfaces will show at once whether the machine has shifted during this interval.

Sec. 14.23

Q. What can be done to remedy the situation, assuming that the leveling surfaces were not modified before the reconditioning operation on the ways was begun and that subsequently, while the machine was in use, the foundation settled throwing the machine out of alignment?

A. Two solutions suggest themselves, viz:

1. The operator can use the bearing surfaces as a base on which to rest the PRECISION LEVEL. This is feasible provided their form is adaptable. Otherwise, it is necessary to make up special templates, precision V-blocks, cylinders, etc. so that a Datum Plane for testing can be established. This solution presupposes that the bearing surfaces were scraped level at the time they were aligned.

2. Since accurate leveling surfaces are not available, the operator can initiate a trial and error procedure. This is a long, tedious process, involving the driving of shims, one at a time, under various parts of the machine and observing the results on the machine's finished work, i.e. actual machine output.

From the foregoing recommendations it is obvious that accurate leveling surfaces can do much to expedite re-alignment when the foundation settles. Experienced mechanics know that for all practical purposes leveling surfaces are indispensable.

Sec. 14.24

Q. Are all leveling surfaces flat in appearance?

A. Usually these surfaces are flat but on one type of inverted V-way, represented in Fig. 26.26, the upper portion of the inverted V is rounded. The rounded portion is not a bearing surface but may be roughened by dent burrs. After removing these it is feasible to file or scrape a very narrow flat space here to modify the leveling surfaces to new conditions.

Sec. 14.25

Q. Why are leveling surfaces usually non-bearing surfaces?

A. Since a machine may require re-leveling from time to time, it is well to have a leveling surface that is not subject to wear and therefore able to retain its original accuracy.

Sec. 14.26

Q. Is there any relationship between leveling surfaces and bearing surfaces?

A. There is no alignment involved between the two types of surface. The leveling surfaces are in the horizontal plane, but the ways do not necessarily have to be likewise. In other words, the bearing surfaces may assume any haphazard angular relationship to the leveling surfaces without affecting the alignment of the machine.

Sec. 14.27

Q. Is there any significance attached to the fact the leveling surfaces and bearing surfaces of a machine are usually parallel to each other?

A. One reason why there seems to be some relationship is that due to manufacturing practice they often are machined parallel for convenience and economy.

Another reason why the two types of surfaces appear to be parallel is that much of the reconditioning work done on both of them is checked with a PRECISION LEVEL. Since this tool will function only in a close approximation to dead level, it is understandable why there seems to be a definite attempt to maintain parallelism between the two surfaces. Actually such parallelism, when it exists, is purely coincidental, and no significance should be attached thereto.

Sec. 14.28
Dead Level

The expressions "level transversely" and "level longitudinally" are used frequently throughout this book. As used here, these terms simply bring to the reader's attention the idea that the surface must be leveled in the direction specified, and other considerations are disregarded for the time being. The surface in question may or may not be level in the other direction. If it is level, both transversely and longitudinally, without tolerance, it is called "dead level."

Chapter 15

TEST BARS

Although the devices known variously as test bars, precision cylinders, or dummy spindles are ground on cylindrical grinding machines and are not hand scraped, they nonetheless belong in a book on scraping. In the first place, test bars are indispensable in conducting alignment tests on many machine members. Secondly, they are made up by the machine shop at the order of the scraping operator and according to his specifications. Therefore, the scraper should be informed as to the types of test bars most frequently utilized in scraping work and the advantages and applications of each.

Sec. 15.1
Kinds of Test Bars

Test bars are preferably made of tool steel, hardened and precision ground. However, for less critical work they are often considered adequate if made of bar stock, turned and polished or ground, depending upon the degree of accuracy needed.

There are several designs of test bars that are commonly used, each being suited for a limited type of service.

The Tapered Shank Test Bar

This is a type of test bar having a tapered shank formed on one end to support the bar. The shank is made to fit a spindle having a tapered hole, and the cylindrical portion is made 12" in length, or in multiples thereof, to accommodate the job. Sag will be reduced if the bar is designed so that the diameter of the srtaight portion is somewhat smaller than the largest diameter of the tapered portion. The bar is sometimes tapped or threaded at the tapered end so that it may be held in place with a draw-in bolt. See (A) in Fig. 15.1.

A tapered shank test bar designed for maximum strength and minimum sag will have the cylindrical portion of the bar hollow. The formation of the inside diameter is a process calling for careful mathematical calculation. For those who have need of them, Tables and Methods are available in standard works of reference. Suffice to say that the hollowed out portion is of varying diameters. That is, the diameter closest to the taper is the smallest and it becomes progressively large towards the free end.

After the inside diameter has been formed, the end is plugged and the center holes at both ends are recessed for protection. Next the bar is precision ground to the specified O. D.

Each and every time before the test bar is used it should be given a precautionary check to determine if the axis of the cylindrical portion and the axis of the taper shank are in-line with their axis of rotation. This can be ascertained by executing a Test Between Centers. (See Sec. 15.11)

NOTE:

For occasions requiring less than maximum accuracy, the close calculation of the inside diameters, mentioned above,

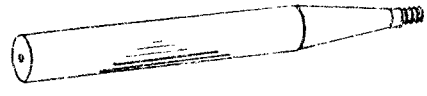


Fig. 15.1(a) Tapered shank test bar.

Fig. 15.1(b) Cylindrical test bar.

Fig. 15.1(c) Cylindrical test bar ground to multiple diameters.

can be dispensed with. An approximation to maximum strength and minimum sag can be effected by drilling the cylindrical portion of the bar to reduce the weight of this section about 50%. For example:

Bar stock 12" long 1" dia.
Weight of section 2.67 lbs.
Drilled hole 3/4" dia.
Wt. of material 1.50 lbs.
Weight reduction equivalent to 56%

Sec. 15.2
The CYLINDRICAL Test Bar

Another familiar form of test bar is that of a perfect cylinder. It is made in various lengths and diameters depending on the individual job. See (B) in Fig. 15.1. It is usually employed in conjunction with V-ways or between centers.

When used in a V-way, the greatest accuracy will be obtained when the bar is in contact with the sides of the V- at some point approximately at the middle half, as measured from top to bottom. The reason that this position is chosen is that invariably the middle section is more accurately scraped than the edge. When calculating what diameter to make the bar, a point not to be overlooked is that to be serviceable the cylinder must extend above the V- in which it is laid, and if there are leveling surfaces, to extend above them also.

For tests between centers, the cylindrical bar, like the tapered bar, should be made hollow to minimize sag. For testing true running, the ends of the cylindrical bar must be protected from damage. This is accomplished by plugging the ends and countersinking the center holes.

A more complex construction is shown at (C) in Fig. 15.1. It is a cylindrical bar having several diameters, each performing a separate function. Such a gage may, for example, be employed to check the alignment of the wheel slide of the cylindrical grinding machine. Refer to Sec. 29.44.

Sec. 15.3
Dummy Spindle Test Bars

There is another classification of precision test bars known as dummy spindles. It comprises designs wherein an inner head or rotor is rotatable within an outer shell or casing, or vice versa, depending upon the application. In the accompanying diagram, Fig. 15.2, a cone and cup type is illustrated. All parts are hardened and ground and usually the bearing surfaces are lapped.

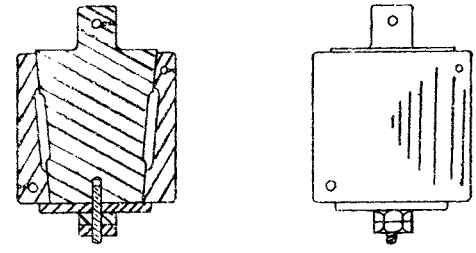


Fig. 15.2 Dummy spindle test bars (Cone and Cup Type)

Fig. 15.3 shows a construction having the inner and outer parts hardened and ground and equipped with precision ball bearings.

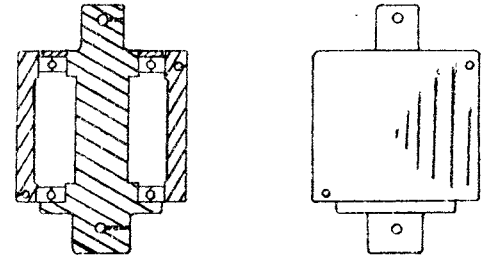


Fig. 15.3 Dummy spindle test bar, hardened and ground and equipped with precision ball bearings.

The rotor and casing of these test bars are made in many different shapes and sizes. They are drilled, tapped, formed or slotted for a variety of applications useful in scraping operations. In combination with various attachments, they are utilized to conduct tests for levelness, swing round tests, tests for parallelism and for right angle alignments etc.

These gages are often made up with the outside diameters of the casings being held to close limits.

The inner and outer sections must be perfectly free to rotate around each other and this movement must be very smooth. Sticking or hesitation of any kind cannot be tolerated because false readings will

inevitably result. Only cylinders that are precision built have any value to the scraper. In other words, accuracy in the test bar is essential, and the scraping operator should insist on it.

NOTE:
The term "dummy spindle" is sometimes used to designate a specially designed test bar that is substituted for the regular spindle of a machine. Refer to Sec. 27.6.

Sec. 15.4
Grinding errors affecting Test Bars

Test bars, in general, are subject to a number of errors or faults which impair their accuracy. Therefore, on receiving a test bar from the machine department, the scraper should immediately check the accuracy of the bar before using it. The possible defects are enumerated below together with practical tests.

1. Ellipticity in the cylindrical section
   Out of roundness in a bar, as shown in exaggerated cross section in Fig. 15.4(a), may be discovered with a micrometer by measuring the vertical and horizontal diameters and at intermediate positions.

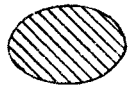


Fig. 15.4(a) Grinding error showing ellipticity in the cylindrical portion of test bar (cross section).

2. A taper in the cylindrical section
   The taper in the bar represented in Fig. 15.4(b) is detected by measuring from end to end with a micrometer.

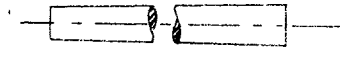


Fig. 15.4(b) Grinding error showing longitudinal taper in the cylindrical portion of test bar.

Additional errors may occur in tapered shank test bars, such as:

3. A divergence of the axis of the tapered shank from that of the axis of the cylindrical section.
   Fig. 15.4(c) shows the error diagrammatically. To test for this possibility, mount the test bar between centers and test for concentricity on both straight and tapered portions using a DIAL INDICATOR.

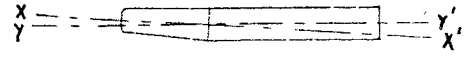


Fig. 15.4(c) Grinding error showing divergence of axis of straight portion (y-y') from axis of tapered portion (x-x') of test bar.

4. Shank non-conforming to the desired taper
   To determine this characteristic diagrammed in Fig. 15.4(d) the following procedure is recommended. Spread a thin coat of bluing on the tapered portion of the test bar. Insert the bar into the spindle hole and wring it a quarter turn, employing considerable pressure. After removing the bar, examine the shank and the hole. Uniform markings over the length is a sign of good fit. If the markings are not uniform it is an indication of a nonconforming taper, unless the streaks suggest dirt particles or burrs. Cleaning or removing the burrs from the bar and hole and repeating the procedure will resolve these doubts.

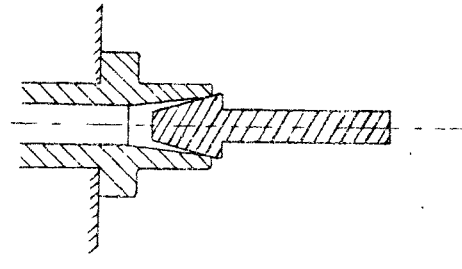


Fig. 15.4(d) Grinding error showing taper of shank nonconforming to taper of spindle hole.

Sec. 15.5
Bushing a Test Bar

The inexperienced operator should realize at the outset that it is almost always necessary to make one or more new bars for each rescraped machine. Each member usually requires a particular form in order to secure the necessary alignment. Furthermore, it is seldom they can be used interchangeably between members. In view of this, a test bar having a tapered shank should never be "bushed" in order to fit it to a tapered spindle hole of larger size or different taper. Should this be done there is always the danger of misalignment in case the tapers fail to match exactly.

Sec. 15.6
Run Out Test

The run out test is performed to determine if a tapered shank test bar inserted in a tapered hole of a spindle, is a true and accurate extension of that spindle. It is a required test on all machine members equipped with a rotating spindle and must be executed each time the bar is inserted. For details of testing the extension of a ram or non-rotating spindle refer to Sec. 15.13 (Testing extension of Non-rotating spindle).

Before making this test, the problem is to properly seat the tapered shank of the test bar into the tapered hole of the spindle.

PREPARATION: or SEATING the Bar.

Proper seating means that the two tapers have over-all area contact.

Several factors may prevent this intimate union. Included are, incorrect taper on the test bar, burrs or ridges in the tapered spindle hole or dirt between the two surfaces. To detect these conditions and insure proper seating preparatory to conducting the run out test, the following procedure is adopted.

A thin film of bluing is spread on the test bar. Then the bar is inserted into the spindle hole and the two are wrung together. After removing the bar, both it and the hole should be examined. Search is made for streaks which signify the presence of burrs and particles of foreign matter; and for non-uniform markings over the length of the taper which indicate poor fit. If these signs are not in evidence, the surfaces can be cleaned and the test bar re-inserted. We now have assurance of proper seating of the bar in the hole and can proceed with the run out test.

EXECUTION: of Run Out Test

The run out test is executed with equal facility and accuracy either at the machine location or at a work bench. If the spindle is contained in a main casting, as in the case of a horizontal milling machine, the test is conducted on the spot. On the other hand, if the spindle is located in a removable member, such as a lathe headstock, the job may be performed just as correctly at a bench. The procedure is as follows:

A DIAL INDICATOR attached to a SURFACE GAGE or other stand is placed convenient to the spindle. As an alternative the INDICATOR may be fastened directly to the machine. In either case, the prime consideration is to prevent any movement of the instrument other than the plunger action of the button. The button is set in contact with the test bar near the spindle nose. By revolving the spindle a reading can be taken. Then the apparatus is moved to the free end of the bar and another reading is obtained. An eccentricity of movement of .00025" at the spindle nose and .0005" at a point 12" away, is usually acceptable. Where greater precision is wanted on a specific machine, the ALIGNMENT TEST CARD will so state by providing a closer tolerance.

Since we have previously tested the bar for proper seating, we know that burrs or dirt cannot cause error. We have also tested the accuracy of the tapers. Thus if no error is found during the present run out test, we will know that the test bar in the spindle represents a true and accurate extension of the spindle. Alignment tests of unquestioned accuracy may now be performed with it.

On the other hand, if the permissible tolerance is exceeded, the fault may be located in one or more of the following sources, viz:

1. Bent spindle
2. Defective spindle bearings

3. Tapered hole not in-line with the axis of rotation of spindle due to an inaccurate grinding set up.

The fault when located must be corrected. The work is judged correctly done if a run out test shows the tolerance is not exceeded. Not till then can alignment tests be performed accurately with the test bar.

A run out test is repeated each and every time a tapered shank test bar is inserted into a spindle hole. On these subsequent tests the only purpose is to determine if the bar is being properly seated. While it is true this matter was investigated previously, frequent removal and handling of the bar may have resulted in minor damage, i.e. burrs. At the very least, grit or dust particles may adhere to the surfaces. It is essential to know that the bar is not partially cocked before alignment tests are made, hence the reason for the repetition.

Sec. 15.7
Sag in Test Bars

Test bars are subject to natural sag due to their own weight. The effect of sag is often overlooked and unless allowed for during alignment tests it becomes a major source of error, particularly on bars having considerable length. The reason this factor is sometimes ignored is due principally to a lack of information as to the amount of sag developed by a bar.

Natural sag in a test bar constitutes a large percentage of the close tolerance allowed on modern precision machine tools. Deflection is greater with a test bar held at one end than when supported at both ends. Solid bars are more affected than hollow bars.

The effect of sag can best be illustrated by an actual example. The vertical alignment of the lathe headstock, that is, the axis of the headstock spindle, must be parallel with the bed ways. A maximum tolerance of 0.0005" inch per foot is allowed at the free end of the bar as measured on the vertical diameter.

Tests show that when a solid tapered shank test bar 1" in diameter and 12" long is employed, the natural sag of the free end will be 0.00038". This amounts to about 75% of the maximum tolerance. Obviously, this is far too much and if not taken into consideration could throw the alignment off by a wide margin. On the other hand, a hollow test bar of the same dimensions will have an approximate sag of 0.00016" which is well within the allowed error.

As regards test bars supported at both ends, the difference in sag between a solid and hollow test bar is not so pronounced. However, in any precise alignment test the amount of sag must be taken into account.

In lieu of specific data by which to estimate natural sag in test bars, a few general principles may be useful as a rule of thumb. They are summarized as follows:

1. A test bar supported at both ends sags less than when held at one end only.
2. A solid test bar will sag more than a hollow bar.
3. On bars of equal length the sag decreases as the diameter is enlarged.
4. Short bars sag less than long bars.

Sec. 15.8
The Target

That portion of the test bar against which measurements are made is called the target. In other words, the target is that part of the surface on which the contact button of a DIAL INDICATOR or base of a PRECISION LEVEL may rest at any given moment. It may comprise a part or all of the total length of the test bar.

Sec. 15.9
Mean Position of the Eccentricity Error

Frequently, for one reason or another, it may be found impossible to seat the test bar in a spindle so that the axis of test bar will be concentric with axis of revolution of the spindle. To minimize the error when conducting an alignment test under such circumstances, the spindle and test bar should be rotated to a position where the latter will present as a target that part of its surface which falls approximately half way between the high and low reading. This particular setting, known as the mean position of the eccentricity error or mean position for short, then will be used for the alignment test. The influence of the eccentricity having been nullified, the

alignment of the test bar to the spindle will be as perfect as it is possible to make it.

Finding the mean position of eccentricity error is a first step in all tests wherein the bar is checked end to end in either the vertical or horizontal planes. However, the mean position of the eccentricity error can be located only if the test bar is inserted in a rotating spindle. It is not a factor when the test bar is inserted in a ram or stationary type spindle.

Fig. 15.5 illustrates the method of finding the mean position on a test bar. As an example, we will use the problem of checking the vertical head stock alignment of a lathe. The tolerance for this test permits a 0.0005 inch per foot rise in the test bar towards the free end.

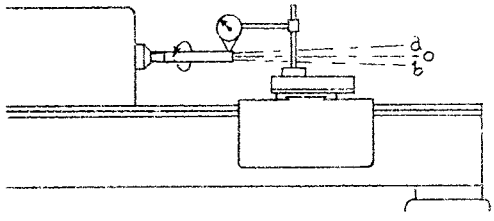


Fig. 15.5 Performing run out test to locate mean position of eccentricity error.

Since the test must be conducted in the vertical plane, we place the contact point of the DIAL INDICATOR on the target at the vertical diameter. The spindle and test bar are rotated 360° and a maximum reading, as at "a" and a minimum reading, as at "b" will be observed. The test bar must now be turned until the position halfway between the high and low readings is situated at the vertical diameter. This will be the mean position of its eccentricity error.

The spindle remains stationary in this position while the alignment test is being conducted.

Sec. 15.10
Adjusting a DIAL INDICATOR button to a test bar.

As we have explained heretofore, a test bar is often utilized to extend the axis of a spindle to facilitate the alignment of ways and slides. When a DIAL INDICATOR is employed as the measuring device to test this alignment, certain precautions must be taken to ensure accurate readings in both the vertical and horizontal planes.

In preliminary tests it is unnecessary to be unduly fussy when adjusting the button of the instrument to the test bar. Usually the button is positioned on the vertical diameter (or horizontal diameter) quite satisfactorily judging by eye. It is only when the final tests are being conducted and minute details have added importance, that more elaborate procedures need be taken.

If the vertical diameter is to be located, the DIAL INDICATOR button is moved horizontally back and forth across, (or underneath) the test bar in a direction square with the axis of bar. In practice this is done by manually moving the Surface Gage and attached DIAL or by mechanically traversing a machine part to which the instrument is fastened. Maximum readings are taken at both ends of the test bar and the difference represents the misalignment between the surface supporting the DIAL and the axis of the bar. See Fig. 27.90a.

NOTE:

The position of the pointer before it begins to recede is the maximum reading or deflection referred to. This is shown diagrammatically in Fig. 15.6.

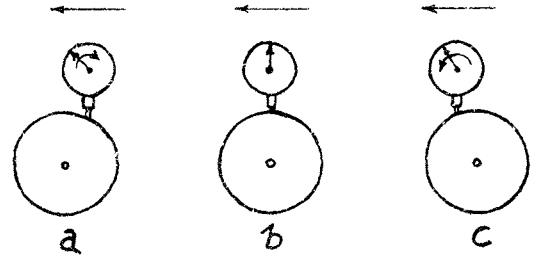


Fig. 15.6 Method of locating the plunger button of DIAL INDICATOR precisely at the vertical diameter of test bar.

(a) Start - INDICATOR hand is actuated as instrument is advanced (b) Vertical diameter is reached when INDICATOR hand registers maximum swing. (c) As vertical diameter is passed, INDICATOR hand begins to recede.

To locate the horizontal diameter of a test bar the button of the DIAL INDICATOR is moved vertically in a direction square with axis of bar. This is accomplished by

raising and lowering the DIAL INDICATOR. Elevating the machine part holding the instrument is the simplest way to actuate it. The maximum deflection is noted at both ends of the bar and the difference in readings represents the misalignment existing between the surface guiding the DIAL INDICATOR and the axis of test bar. See Fig. 27.90b.

Sec. 15.11
Test Between Centers

Test bars whether cylindrical or taper shank, are supported at the ends between dead centers while being ground to size. When finished the axis of the bar is, or should be in-line with the axis of revolution.

Since use and abuse have a cumulative effect, the accuracy of the test bar should be verified from time to time. It is obvious that a bent test bar has no value, whatsoever, to a scraper.

One practical method whereby the accuracy of a test bar can be determined would be to duplicate the set up by which it was first produced. This is done by mounting the test bar in question between centers, usually on a lathe. By this test we seek to prove that the axis of the bar is in-line with its axis of rotation. And if such is found to be the case, the test bar has retained its original accuracy. The testing procedure is as follows:

1. The center holes of the test bar are thoroughly cleaned and if thought necessary are tested for burrs with a 60° center using marking compound as the indicating medium.
2. The centers of the lathe, grinder or other testing machine are inspected and replaced if found defective due to wear or abuse. The centers used must be perfect cones of a 60° angle.
3. The test bar is placed between centers which are adjusted to provide a slight tension to the bar. This eliminates all looseness or end play and provides the most favorable conditions for accurate testing.
4. A DIAL INDICATOR is mounted adjacent to the test bar and adjusted so that the plunger makes contact with the surface of the bar at, say, one end.
5. The bar is revolved by hand between dead centers and the pointer of the DIAL is watched for any movement.
6. A reading is taken successively at each end of the bar and at intermediate positions.
7. If each reading taken is constant throughout 360° of revolution, the test bar is perfect. That is, its axis coincides with the axis of revolution of the bar.
8. If out of true is indicated by a fluctuation of the pointer at one or more of the positions tested, the operator must decide whether it constitutes too large a percent of the tolerance allowed for the application for which the test bar is intended.
9. The type of test bar, cylindrical or taper shank, is unimportant. Both are tested in precisely the same manner. The contact pressure of the DIAL INDICATOR at various points along the bar is also immaterial. The all important thing is whether or not the pointer is displaced while the test bar is revolved.

Sec. 15.12
Alternative Test for Eccentricity of Test Bar

All test bars should have their center holes recessed or otherwise well protected from damage so that if an error is observed during the test it can be logically assumed that the fault lies not with the center holes but with the surface of the test bar.

If the center holes of the test bar have been damaged it is advisable to adopt an alternative procedure, namely:

Lay the test bar in precision V-blocks placed on a SURFACE PLATE. Set a Surface Gage with attached DIAL INDICATOR close by. Adjust the button of the instrument to touch the test bar. Revolve the bar slowly through 360° being careful not to move the V-blocks. Take readings at several places on the cylindrical portion and on the tapered section if any. A movement of the pointer arm as the bar is turned indicates eccentricity.

Sec. 15.13
Testing Extension of Non-rotating Spindle

The test between centers has another

useful application in testing the alignment of the axis of the tapered hole with the axis of movement of a ram or non-rotating spindle. The test bar is utilized on these occasions to extend the target length, thereby permitting alignment tests to be performed indirectly on the ram or non-rotating spindle.

The procedure is as follows:

1. The tapered shank test bar has previously been tested and found to be accurate.
2. The ram is removed from its housing and its tapered hole cleaned.
3. Proper seating between the test bar and ram is assured by inspecting for burrs and proving the equality of tapers. These matters are determined by applying a thin coating of marking compound in a ribbon-like strip to the tapered portion of the test bar. The bar is inserted in the tapered hole of the ram. The two parts are wrung together, separated and inspected. Streaks on the transferred marking denote burrs. If the markings are uniform it signifies that the test bar can be properly seated in the ram.
4. The test bar is inserted into the ram and the unit placed between centers. The testing procedure is the same as previously described for the test bar alone.
5. If the pointer of the DIAL INDICATOR shows no fluctuation at any point tested on either the bar or ram, while the unit is revolved, then the axis of the tapered hole in the ram is in-line with the axis of revolution of the ram (and hence of its axis of movement.) It is possible, therefore, to treat the inserted test bar as a true extension of the ram, and alignment tests made to the test bar may be construed as being performed on the ram itself.

Chapter 16

THE DIAL INDICATOR

The DIAL INDICATOR will record with suitable accuracy only when properly used. Since there are a number of reasons why eccentricities creep into the readings, it might be advisable to point out their cause and suggest preventive measures. Although this instrument is a familiar device, both machinists and novices will benefit by a study of its special applications to reconditioning work on machine tools.

Sec. 16.1
The Dial Indicator

The DIAL INDICATOR is one of the most frequently used tools for aligning operations. It provides the operator with a means for making comparative measurements. That is, it indicates how test surfaces compare in height, distance, concentricity, or angular inclination from a Datum Point. It is a type of measuring instrument wherein the personal factor is not an influence of major importance. The sense of touch, so essential to the accurate utilization of some tools, for example, micrometers or feeler gages, is not required when employing this device.

The DIAL INDICATOR is used most often in conjunction with either a surface gage or an indicating jig, though when conditions permit, it can be affixed directly to a machine member. Incidentally, apparatus employed to hold the DIAL INDICATOR should be as compact and rigid as possible to minimize any error due to bending of the support.

DIAL INDICATORS are usually graduated into "thousandths", "half thousandths", and in "tenths." Those graduated in "half thousandths" are sufficiently precise for alignment tests on most machine tools.

The pressure required to actuate a DIAL INDICATOR varies from instrument to instrument. For alignment testing it is preferable to select a model having low contact pressure (minimum spring tension.) This is an important consideration on some tests where the tension imposed by the spring of the instrument would bend the rod holding the device thereby impairing accuracy.

When readings are taken with a DIAL INDICATOR, a movement across the test surface is permissible in only one direction. The choice of direction is at the discretion of the operator. Whether the INDICATOR button moves or the test surface traverses is immaterial. The important consideration is that the reading be taken only

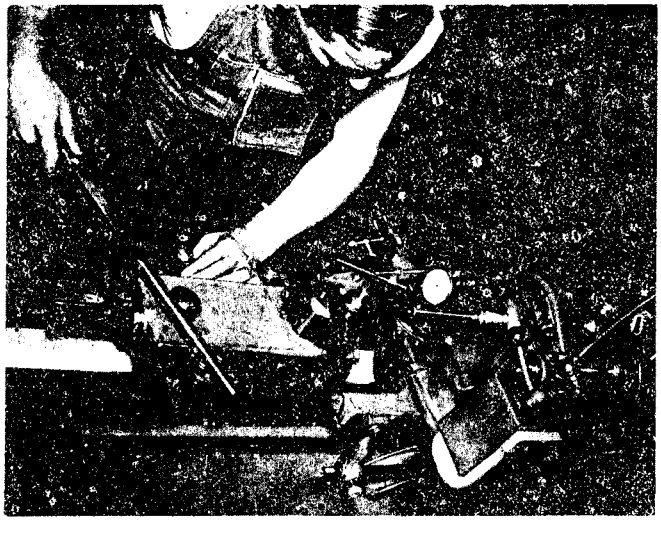


PLATE 13. Testing the alignment of the turret slide, using a DIAL INDICATOR mounted in the turret head, with the indicator button resting on a test bar in the headstock spindle of the lathe. (Courtesy - South Bend Lathe Works.)

when moving in the selected direction. Fluctuations in the pointer while the button is returning to the starting point for a repeat test, are to be disregarded.

Sec. 16.2
The Dial Indicator in testing methods

In general, four methods of utilizing the DIAL INDICATOR for alignment testing are employed, although there are numerous variations of these fundamental procedures. Each method will be described together with its advantages and disadvantages. Examples are supplied where further clarification is desirable. The applications are enumerated as follows:

1. The direct method
2. The swing-round method
3. The double test bar method
4. The slip bushing method

Sec. 16.3
The Direct Method

This is the most common system of applying the DIAL INDICATOR. The Direct Method is so-called because it can be utilized without the preliminary preparation of special fixtures. The instrument may be stationary and give readings as the surface to be indicated moves past. The device can also be affixed to a Surface Gage or Indicating Jig and provide readings as it is moved along the surface to be checked. Rigidity of the holder for the DIAL INDICATOR is of paramount importance in these applications. On most set ups ample room is usually available so that substantial supports can be used.

An example of the straight line movement is shown in Fig. 16.19 wherein dovetails are being tested for parallelism.

A rotary movement is illustrated in Fig. 15.5. Here the axes of the spindle and test bar are being checked for concentricity.

Sec. 16.4
The Swing-Round Method

This is a basic measuring method employing a DIAL INDICATOR. The instrument should be of dependable quality so the results of the tests may be relied on.

The alignment tests performed by this method fall into two classifications, namely:

1. 90° alignments
2. Center line or parallel alignments.

An example of the first procedure is represented in Fig. 27.7. It shows the face of the column of a horizontal milling machine being checked for alignment with the spindle. The DIAL INDICATOR is fastened to the spindle by a rod and measurements are taken 180° apart. The difference between the two readings gives the amount of error in the alignment between the points measured.

With the set up described above, the flexibility of the extension rod will be the main source of error.

The second classification is illustrated in Fig. 16.1. Here the hole in the arbor support is being checked for alignment with the horizontal milling machine spindle. The alignment of two shafts or spindles is concerned with the deviation of their axes from a common center line. When the swing-round method is utilized

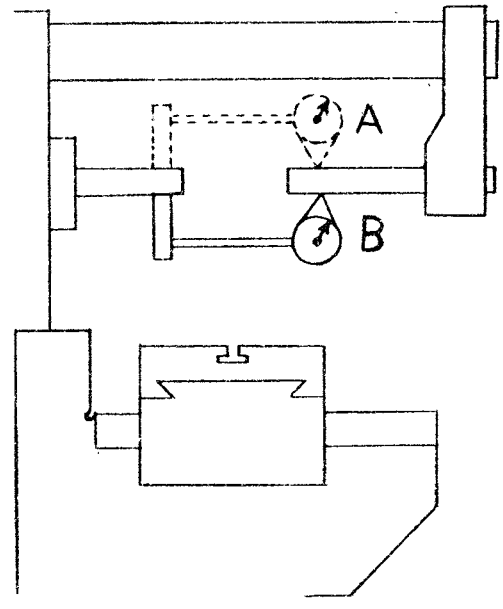


Fig. 16.1 View showing swing-round method of applying DIAL INDICATOR to check alignment of arbor support hole with spindle of Horizontal Milling Machine.

for the test, the deflection of the pointer on the Dial Gage may deviate by twice the allowed error.

This set up is subject to a number of possible errors, among them are:

1. The natural sag of the test bar affects accuracy, but this can be minimized by making the bar hollow:
2. Maintaining rigidity in the holder for the DIAL INDICATOR is of major importance in securing accuracy. Flexibility must be eliminated to reduce

   For example, a holder consisting of rods of various lengths and small diameters, fastened together by pressure through some locking mechanism is always subject to distortion, particularly from careless handling, and should never be used.

   The potential error in this set up can be effectively cancelled out by using a hollow cylindrical housing, instead of a holder made of rods. The cylinder should be about 3" O.D. with 1/8" w It need not be ground. This hollow tube is pressed on a tapered shank inserted into the spindle. Centering is not required. A DIAL INDICATOR is mounted at the free end of the cylinder, as represented in Fig. 16.2. The natural sag in this arrangement is imperceptible. A DIAL actuated by a low contact pressure is preferable with this setup.
3. The eccentricity of the spindle during rotation, due to a fault in the bearings, will be another cause of inaccuracies.

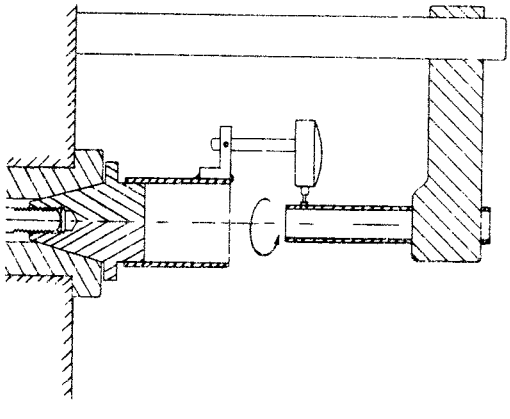


Fig. 16.2 Example of rigid holder used to increase accuracy of swing-round test. A cylinder press fit on a taper shank is inserted in spindle.

It can be rectified only by fitting new bearings.

Sec. 16.5
The Double Test Bar Method

With this system we can check an alignment, not directly, but from a Datum Plane. Such a plane may take the form of a SURFACE PLATE, a bearing surface or any other suitable base.

An adaptation of this method is the alignment of the arbor support hole to the spindle of a horizontal milling machine. Two test bars of identical diameter are required. One bar must have a tapered shank to fit the spindle. The axis of the tapered test bar must be aligned with the axis of the spindle. This is determined by a run out test. Next the test bar is turned to the mean position of its eccentricity error placing it at either the vertical or horizontal diameter, as required. The other test bar which is the straight cylindrical type is now inserted into the arbor support bearing.

Since testing the vertical plane is somewhat different from testing the horizontal plane, each procedure will be separately explained.

We test one bar against the other in the vertical plane as follows:

A DIAL INDICATOR is affixed to a Surface Gage and the assembly clamped to the top of the table of the milling machine, as shown in Fig. 16.3(a). In this

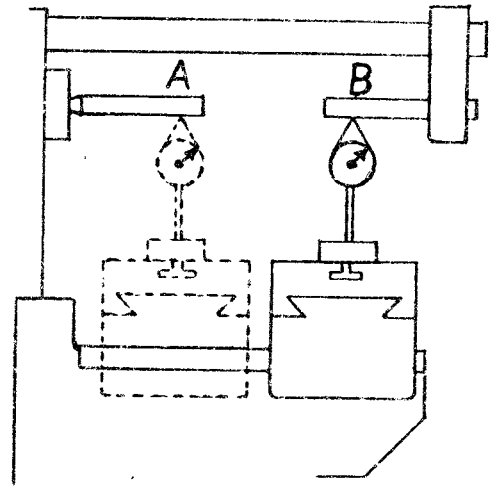


Fig. 16.3(a) Example of double test bar method checking on vertical diameter.

application the knee flat ways serve as the Datum Plane.

The button of the DIAL INDICATOR can be positioned either at the top or underneath the bar. This choice will depend upon convenience only as the same accuracy is obtainable in either location.

As the table is moved longitudinally, the DIAL is passed underneath the free end of test bar (A). The motion of the table is halted when the maximum swing of the DIAL pointer indicates that the vertical diameter has been located. This reading is noted.

Then the saddle-table assembly is moved outward until the INDICATOR reaches a position underneath the free end of test bar (B). The table is again moved longitudinally until the DIAL indicates by the maximum deflection of the pointer that it is positioned at the vertical diameter. This reading is noted and compared with the previous reading to determine whether or not the tolerance for this particular alignment has been exceeded. This set up illustrates a method of checking the alignment of the arbor hole with the axis of the spindle in the vertical plane.

To check test bar (A) against bar (B) in the horizontal plane some changes in the set up previously used are called for. In the first place, test bar (A) is turned so that the mean position of eccentricity error is located at the horizontal diameter. The button of the DIAL is touched to the free end of the bar approximately at the horizontal diameter, as shown in Fig. 16.3(b). A slight pressure should be applied to the plunger to actuate the pointer.

The knee-saddle-table assembly is raised and lowered until the pointer of the DIAL attains its maximum swing which denotes the horizontal diameter of the test bar. The DIAL is now zeroed.

Next the saddle-table assembly is moved outward on the knee and the motion is stopped when the INDICATOR plunger is resting on the free end of test bar (B). Any change in the reading will denote the amount of misalignment and its direction.

In analyzing the above procedure, the critical reader might object that the knee flat ways are slightly higher towards the front of the machine due to the unilateral tolerance usually required. (See Sec. 27.35) However, the slight error thus developed in moving the saddle-table assembly from one test bar to another is small and may be ignored if the vertical alignment of these members is within the tolerance allowed for that particular machine. This alignment will, of course, have been previously checked.

Similarly, the accuracy of alignment of the knee guiding way will affect the reading in the horizontal plane. (See Sec. 27.35) But it, too, may be ignored as trifling, if the alignment of the knee guiding way to the column face is within the tolerance allowed.

Listed below are other possible faults affecting the reliability of the Double Test Bar Method in all applications.

1. The elongated support for the DIAL INDICATOR is another weak point. Unless the supporting rod is very rigid and resistant to bending, and used in conjunction with an instrument of low contact pressure, the readings may be adversely affected.
2. Natural sag of the test bars is always present. However, its influence can be diminished by utilizing hollow test bars.
3. Incompatibility of a test bar to the spindle is also a frequent obstacle to accurate results in alignment testing. This is the case when a spindle hole is

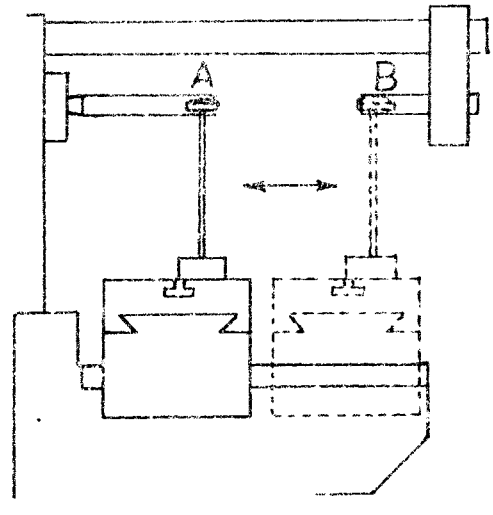


Fig. 16.3(b) Example of double test bar method checking on horizontal diameter.

neither tapered nor possessed of a collet attachment. Consequently, neither a tapered shank nor straight test bar is insertable. However, if the test is to be executed at all, a test bar must be aligned with the spindle. Of course, some sort of attachment can always be fastened to the spindle, but to fit the test bar to the attachment and then align the bar with the spindle axis is not an easy matter. The axis of the test bar must be in-line with the axis of rotation of the spindle. Considerable testing and adjustment of the set up will be necessary in these cases.

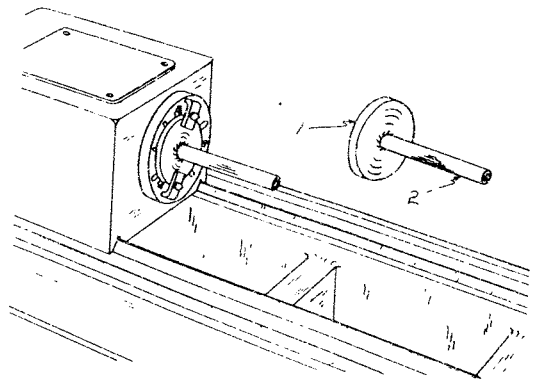


Fig. 16.5 (top) Adjustable test bar consisting of a hollow tube (2) welded to a flange (1).

(bottom) Showing method of adjusting test bar by clamping to a face plate and shimming.

Sec. 16.6
Universal Test Bars

Many types of universal test bars have been developed to cope with the problem just mentioned, namely, aligning the test bar with the axis of spindle. One solution is shown in Fig. 16.4. The bar illustrated

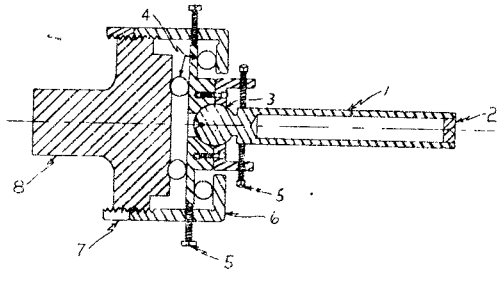


Fig. 16.4 Longitudinal sectional view of a universal type test bar.

(1) Test bar (2) Plug (3) Ball and socket (4) Ball bearings (5) Adjusting screws (6) Outer casing (7) Locking nut (8) Shank

is designed to be gripped by a chuck, or with some modification, to be bolted to a face plate. It is completely universal and is adaptable to a quick truing up. Such devices need not always be so complex to be efficient.

One alternative arrangement shown in Fig. 16.5 represents a round flange (1) welded on the end of a tube (2) which is ground to match the diameter of the bar used opposite. The flange is clamped to a face plate, shimmed where needed and trued up.

Regardless of the set up used by the operator, the double test bar method is dependent upon the accuracy with which the axis of the test bar associated with the spindle is centered with respect to the axis of the spindle. The eccentricity error is eliminated as a factor in the measuring results by turning the test bar to the mean position.

On the other hand, a test bar for a non-rotating spindle or ram usually presents no comparable problem. To assure its correct positioning the ram is removed from its member. The test bar is inserted into the ram and both are placed between centers and tested for alignment one to the other. If accuracy requirements are satisfied, they are returned to the member and inserted intact. (See Sections 29.27 and 29.28 and 26.50)

Sec. 16.7
The Slip Bushing Method

This testing procedure is sometimes used for checking the alignment of a hole to a spindle. For example, the arbor support bore (1) is aligned to the spindle (2) of a horizontal milling machine, as shown in Fig. 16.6. The alignment is tested in both the vertical and horizontal planes.

Before this test is conducted several facts must be established, namely:

1. The bushing must be a nice sliding fit on the test bar and in the bore of arbor support.
2. The natural sag of the test bar must be known. Even though a hollow bar may

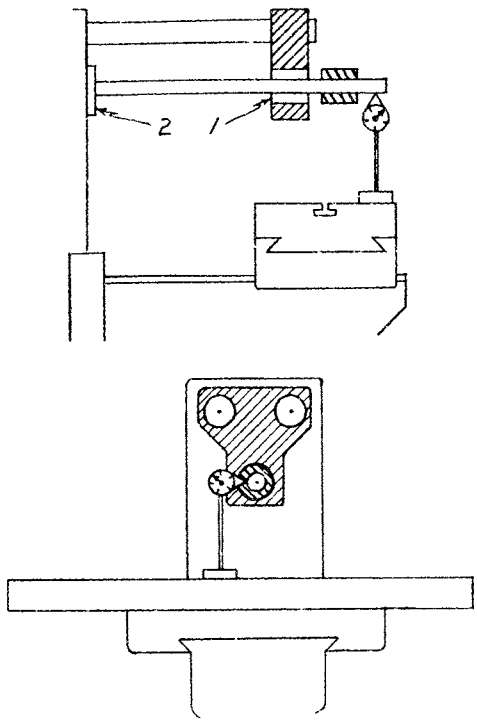


Fig. 16.6 Diagram of slip bushing method testing alignment of arbor support to spindle in the vertical plane (top). Horizontal plane (bottom).

be used it is still relatively long in comparison to its diameter therefore subject to sag.

3. The axis of the test bar must be accurately aligned with the axis of rotation of the spindle. The question of accuracy is determined by conducting a run out test.
4. The position of the DIAL INDICATOR on the test bar must be definitely fixed. But whether it is to be at the top, or underneath, for the vertical check, or on one side or the other for the horizontal check, is a matter of discretion with the operator.
5. When testing the alignment in the vertical plane, the deflection of the test bar due to the weight of the bushing must be known. This is ascertained by mounting the DIAL INDICATOR on a SURFACE GAGE and setting the apparatus on the table top. The button of the DIAL INDICATOR is placed against the test bar, either on top or underneath at the vertical diameter. It is essential for the reading to be taken at the exact vertical diameter. Pressure sufficient to register a reading of say 10 points is imposed and the DIAL zeroed. Then the DIAL INDICATOR is set aside momentarily in order to place the bushing on the test bar. The instrument is now returned to the same position on the test bar i.e. the vertical diameter. Any change in the position of the pointer should be noted and jotted down for future reference.

(We now proceed to the execution of the tests in both planes.)

Sec. 16.8
Testing Alignment in the VERTICAL PLANE (Slip Bushing Method)

Having obtained the essential preliminary information, we are now prepared to test the alignment in the VERTICAL PLANE. This is accomplished by executing the following test.

After placing the bushing on the test bar, the latter is turned to locate the mean position at the vertical plane. The DIAL INDICATOR affixed to a SURFACE GAGE is positioned on the table top. The button of the DIAL is brought into contact with the test bar at the vertical diameter with sufficient pressure to register a reading. (The degree of pressure will be determined by the estimated misalignment and its direction) As the bushing is pushed into the arbor bore, the change in reading, if any, is carefully noted.

This reading is modified by factors No. 2 and No. 5, as given above. The resultant is the amount of misalignment in the vertical plane, of the arbor bore to the spindle.

Sec. 16.9
Testing the Alignment in HORIZONTAL PLANE (Slip Bushing Method)

Still referring to Fig. 16.6 we check the horizontal alignment by turning the mean position of the eccentricity error of the test bar to the horizontal plane. Next the bushing is slipped on the test bar. Then the DIAL INDICATOR button is set at the horizontal diameter of the bar with enough pressure to provide a reading of about 10 points, whereupon the instrument is "zeroed." In this phase of the procedure,

the weight of the bushing and also the natural sag of the bar can be disregarded. By inserting the bushing into the arbor hole, the DIAL pointer will be deflected if there is a misalignment in the horizontal plane.

Sec. 16.10
Adjusting the DIAL INDICATOR

It is possible to adjust the DIAL INDICATOR to show the variation, over or under, the permissible error on a given surface. To accomplish this the DIAL INDICATOR must be "zeroed." That is, when adjusted, it is set to give a reading either way, i.e. plus or minus. The adjustment is made as follows:

1. After securing the instrument to a suitable base, the button is placed in contact with the test surface. Just enough pressure is exerted to give a reading on the DIAL of, say, 10 or 20 points. This pressure is sufficient to provide the necessary plus or minus readings normally expected. On the other hand, it is not excessive to the extent of causing shock damage to the delicate works if it is necessary for the button to make or break contact with the test surface.
2. Holding the instrument in place, the enameled face of the DIAL is spun around so that the index pointer stops on the numeral zero (0). Now any movement of the plunger will cause the pointer to veer to one side or the other of the zero (0) thus providing a plus or minus reading.
3. To assure the reliability of the setting, backlash in the instrument must be compensated. When a straight line movement is involved, this can be done by the simple expedient of deliberately moving the contact point of the DIAL off the test surface. Its path is then retraced to its exact original position, which will be the starting point for the ensuing test. This action should be repeated three or four times. If the index pointer invariably returns to zero (0), no other adjustment of the DIAL face is necessary. It may then be assumed that the action of the working parts of the instrument is stabilized and that the gage is henceforth capable of giving uniform readings in the direction to be tested.

   In cases where the swing-round method is utilized, and no opportunity is presented to vacate the test surface, free working of the plunger may be assured by lifting the button with the finger nail and allowing it to drop back. Then several trial sweeps should be made in the direction the test is to be executed. If backlash has been effectively removed, the pointer will always return to zero (0) after the instrument has completed the circuit to the starting point.
4. All adjustments to the DIAL face to "zero" it are keyed to the readings to be taken. That is, if it is proposed to move the instrument in a certain direction when testing an alignment, the movement to the starting point, to observe if the DIAL face requires readjustment, must be made in the same direction.

   For example, a test chart may show that the reading is made, say, from LEFT to RIGHT. If so, the adjustment is keyed to this direction. On the other hand, if the alignment test requires a reading taken, say, when moving from top to bottom, the DIAL setting is made similarly. Any rotary movement given the DIAL INDICATOR during a test, such as a swing round test, must also be exclusively in one direction, either clockwise or counter-clockwise, but not both ways indiscriminately. The DIAL must be adjusted with this requirement in mind.
5. With the INDICATOR "zeroed" by the approved method ready at the starting point, the test may now be conducted along the test surface. It should be emphasized that the setting is of a temporary nature. The DIAL must be readjusted as each new surface is tested. The same routine; viz, "zeroing", compensating for backlash, and moving to the starting point in the same direction that the test run is to be made, is repeated each and every time. Departing from this proven method results in instability of the instrument and unreliable readings. Testing should not begin until stability is assured. It must then be maintained by unidirectional motion, otherwise the readings obtained cannot

be depended on.

NOTE:

On account of the time necessarily spent in "zeroing" the DIAL, many operators prefer not to undertake this operation when conducting alignment tests, particularly if the instrument is of uncertain quality. Even though the numbered face is not "zeroed", it is nonetheless essential to stabilize the instrument. With the single exception of adjusting the face, all instructions given above must be faithfully observed if the instrument is to function reliably.

Sec. 16.11
Testing Cam Action with a Dial Indicator

Cam action is a sliding motion of a spindle parallel to the axis of rotation, which repeats once each revolution. The sliding motion may be due to manufacturing errors, either in the spindle bearings or in the face of the locating shoulder and collar which may not be in a plane square with the axis of rotation. (See Fig. 16.7) Another cause of cam action might be a bent spindle.

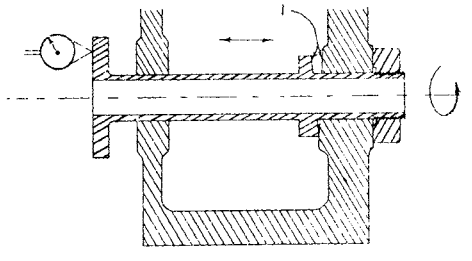


Fig. 16.7 Showing machining error in locating shoulder and collar as one cause of cam action in spindle.

Cam action, if excessive, impairs the accuracy of the machine. Therefore, it is necessary to conduct this test on all rotating spindles.

To measure cam action accurately, end play must be eliminated as a factor. End play refers to the movement of a spindle in the axial direction. Under actual working conditions a certain amount of end play is necessary to prevent the spindle from "seizing" from the effects of heat under load. However, this condition is undesirable when trying to make accurate tests for cam action. It can be controlled by applying an axial thrust of constant force against the spindle. This enhances the reliability of subsequent readings because the end play remains uniform throughout the test.

The test for cam action is executed with a DIAL INDICATOR which should be of highest precision. The instrument is located near the spindle so that the button can be brought into contact with the face as shown in Fig. 16.8. The spindle is slowly revolved and a reading is taken. Then the DIAL button is removed and positioned 180° from the first location. The test is now repeated.

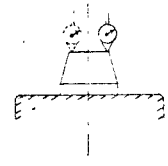


Fig. 16.8 Testing for cam action on face at two points 180° apart to avoid error. (top view)

A word of explanation for this procedure is appropriate. In testing for cam action of a spindle, the DIAL INDICATOR will not be actuated if the DIAL button should inadvertently be positioned at the same height at which a turning tool, machined - or a grinding wheel, ground - the spindle face being tested. To avoid making this mistake, the test for cam action must always be conducted at two points 180° apart on the face of the work spindle. Thus in testing for cam action, the diagrams in alignment test cards will always show the INDICATOR mounted in a position opposite the logical point of machining. Refer to Fig. 26.57 Lathe, Cam Action of Spindle. In this illustration the instrument is positioned on the rear side of the Test Plate.

The chief criticism of the foregoing test is that any surface irregularity will contribute towards increasing the amount of error noted, although usually this will be but a minor part of the whole. To eliminate altogether surface irregularity as a factor in testing cam action, either of two alternative measures can be

adopted. Since both require the preparation of a special plug, if a spindle is to be tested, it is unlikely that either will be used except when the need for the highest precision justifies the extra expense. (Other components, such as lead screws, can be directly tested by these methods without using the plug.)

Essentially what is done is to arrange the line of movement of the DIAL plunger to coincide with the axis of the spindle being tested. That is to say, the button is set on a point in-line with the axis of rotation, such as against the steel ball shown in Fig. 16.9, or in contact with a surface which is square with the axis of rotation, as represented in Fig. 16.10.

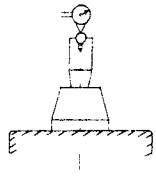


Fig. 16.9 Testing for cam action on point in-line with axis of spindle. Plug is inserted in spindle hole and DIAL button is placed in contact with steel ball. (top view)

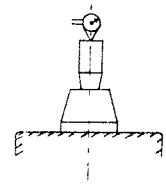


Fig. 16.10 Alternative method of testing for cam action. With DIAL INDICATOR positioned at axis of spindle the effect of surface irregularities is eliminated. (top view)

As the spindle is revolved it should be subject to a constant axial force acting towards the bearing which supports the end thrust. Any movement of the DIAL plunger will now represent cam action only, the factor of surface irregularity having been totally eliminated.

Sec. 16.12
Zero-Zero

The symbol zero-zero appears frequently throughout this book in speaking of readings taken from the DIAL INDICATOR. These readings are made, from and to, a variety of surfaces but in all instances they represent identical heights, widths, slopes, etc. When these tests are performed, it is unnecessary for the DIAL hand to point always to the zero (0) numeral on the face. Any position on the DIAL face may be indicated. The only requirements are that the reading be taken at two separate places on a work surface as far apart as possible, and be identical. If the graduations are 2 - 2 or 9 - 9 or any other number, they are for all practical purposes identical. In other words, when two measurements disclose equal values on the instrument, they are spoken of as a zero-zero reading.

It would be a serious mistake to leave with the reader the impression that when a zero-zero alignment is called for in an alignment test, it means an inelastic dimension. Such a condition might be highly desirable in many instances but for practical reasons some tolerance will always be acceptable. This tolerance may be specified in the alignment test card or left to the discretion of the scraper. In short, the term zero-zero should be construed to mean the theoretical limits modified by the tolerance.

The use of the term is illustrated in Fig. 16.11 where two stepped flat ways,

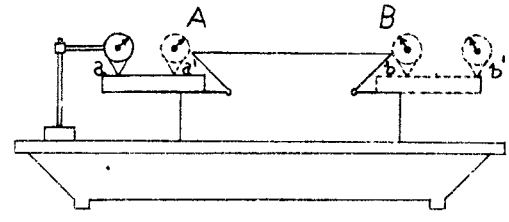


Fig. 16.11 Showing method of measuring stepped flat ways for parallelism. Assume that readings taken at left side are 20-20 and those on right side are 5 - 5. If circumstances required both flat ways to be in the same plane, as well as parallel, then readings at all four positions would have to be identical.

(A) and (B), are measured for parallelism from a common Datum Plane, such as a SURFACE PLATE. In the problem posed, assume the readings taken at a-a' are zero-zero and those taken at b-b' are also

zero-zero. Further assume that this is indicated by the DIAL hand pointing to different numerals in each case thereby showing that each flat way is a varying distance from the SURFACE PLATE. The conclusion to be drawn is that the two flat ways are parallel, although not at the same level. They would be in the same plane (and also parallel) only if the DIAL hand registers identical readings i.e. points to the same numeral at all four points measured.

In order to perform such a test a scraped PARALLEL is held on one flat way and measurements with a DIAL INDICATOR attached to a Surface Gage are made to the extremities of the PARALLEL. The set up is then moved around to the other flat way, and readings are again taken in the same fashion. Although the accompanying illustration, Fig. 16.11, shows only one application of this term, many examples of a zero-zero reading will be demonstrated throughout this book.

Sec. 16.13
The Indicating Jig

The indicating jig, shown in various stages of construction, Fig. 16.13 through Fig. 16.16, is a practical device for checking the parallelism of many types of surfaces which can be conveniently bridged by an apparatus of this kind. It may be constructed in any number of designs to satisfy a variety of test requirements. Though we shall discuss only one form in the following paragraphs, a little ingenuity will enable the reader to devise many others. The indicating jig is usually used in combination with a DIAL INDICATOR.

To illustrate the construction of an indicating jig, the several necessary steps are outlined below, step by step. To further clarify the problem, the indicating jig is built to conform to the hypothetical dimensions of the column of a vertical milling machine. Fig. 16.12 is a cross-sectional, dimensioned top view of the machine.

CONSTRUCTION DETAILS

Take two pieces of 1/4" square cold rolled steel about 15" long and bend each rod as shown in Fig. 16.13. The point marked (A) is rounded off and smoothed

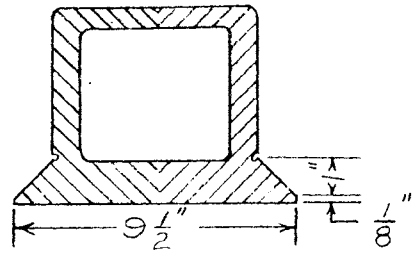


Fig. 16.12 Dimensioned cross-sectional top view of milling machine for which an indicting jig is to be constructed for test purposes.

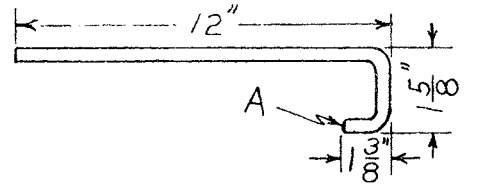


Fig. 16.13 Arm of indicating jig made from 1/4" square C.R. rod.

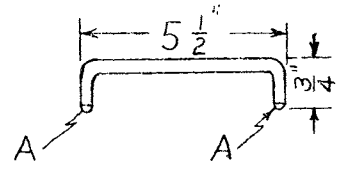


Fig. 16.14 Cross piece of jig.

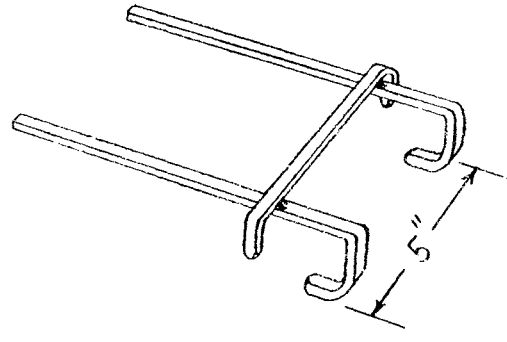


Fig. 16.15 First weld on jig.

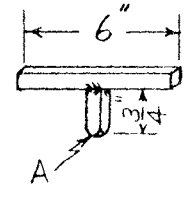


Fig. 16.16 Leg of jig.

with emery cloth. This point rides on the guiding surface of the member, so it is preferable to have a smooth contact that will not scratch the surface. Round off the contact points of all rods that bear on scraped surfaces.

Next take one piece of, 1/4" square x 7" long, cold rolled steel and bend it as shown in Fig. 16.14. Now braze, or weld, the three pieces together as shown in Fig. 16.15. Then weld together the two pieces illustrated in Fig. 16.16. Finally, assemble the parts as represented in Fig. 16.17.

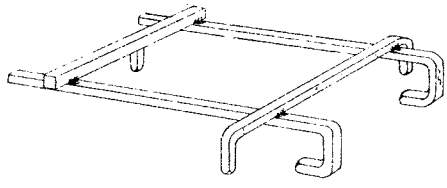


Fig. 16.17 Frame assembled.

Fig. 16.18 shows how a piece of 5/16" round cold rolled steel bent at one end is welded to the device to provide a holder arm. The bent section of this round rod is made sufficiently long so as to provide the DIAL INDICATOR with room to adjust to different positions for a variety of working conditions. In Fig. 16.19 the jig is shown completely assembled with the DIAL INDICATOR attached.

While rather precise specifications were given above, the jig may be constructed of rods of almost any material, even scrap. Furthermore, it is not necessary for the dimensions to be adhered to exactly as they are given here. Even if one or more legs are longer or shorter than the others by 1/4" or so, the jig will automatically center itself and equalize these variations. Thus since precision is not a requirement, a properly functioning jig can be speedily assembled with a minimum of pains.

The one vital requirement is that the jig should have sufficient strength and rigidity so that the pressures and strains imposed while handling it during a check will not cause appreciable bending. This should be prevented because distortion of any kind will induce inaccurate readings in the DIAL INDICATOR.

An essential consideration in the design of an indicating jig is that all of its supporting legs touch surfaces other than the one being tested. Thus a minimum of two surfaces of proven accuracy must be available and adjacent to the test surface before the device can be employed. If this condition cannot be satisfied then other means of testing, such as a PRECISION LEVEL, must be utilized.

In the jig under discussion the legs are arranged as follows:

1. A two point contact should be made on one scrape-finished surface that is being used as the guide for checking parallelism. For example (A) and (B) in Fig. 16.19.

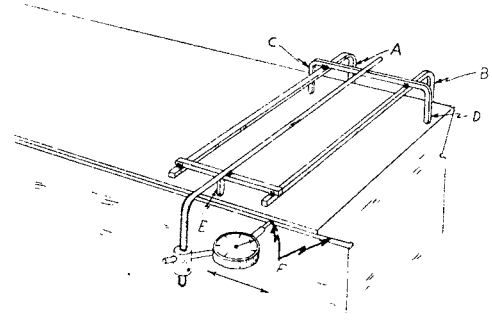


Fig. 16.19 Showing indicating jig with DIAL INDICATOR attached testing dovetails for parallelism.

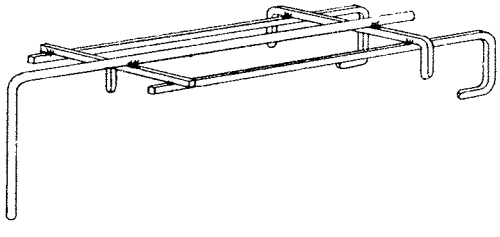


Fig. 16.18 Holder rod attached.

2. A three point contact should be made on an adjacent surface that is also flat and true. For example, (C), (D) and (E) in Fig. 16.19.
3. The contact point of the DIAL INDICATOR must ride against the surface being checked. For example, (F) in Fig. 16.19.

Sec. 16.14
Using the Indicating Jig

Fig. 16.19 shows the indicating jig in actual use testing the parallelism of a dovetail. It will be noted that attached to the jig is a DIAL INDICATOR for which complete instructions were given elsewhere.

Only one precaution is necessary in handling this jig, namely; Hold all of its contact points firmly on the several surfaces of the machine member. Hand pressure will suffice for this. But, conditions permitting, more dependable results are possible if it is weighted by laying any handy pieces of steel across it. This added weight improves its stability. In case weights are added, then the jig requires hand pressure only to hold its legs against the dovetail side and to move it along the surface.

Chapter 17

GIBS: FUNCTION, CONSTRUCTION AND ADJUSTMENT

These essential components in machine design are so commonplace they scarcely need an introduction. However, there are numerous problems involved in making them with which many machinists are not too familiar. Therefore, to clarify various obscure points this important subject is treated in detail.

Sec. 17.1
The function of a GIB

The function of the relatively long, thin strip of metal called a gib is to hold together two mateing members of a machine in such a way that neither their alignment nor their ability to slide freely is impaired. These requirements can be better understood by a prior consideration of mateing members which are connected by gibs.

Any two parts which have sliding bearing, one on the other, are called mateing members. One is designated the stationary member, the other is termed the sliding member. This is not an arbitrary division but is one based on their relation to each other. That is to say, the part that traverses is called the sliding member, and the part across which the sliding member moves is termed the stationary member. Another way to differentiate between them is to say that the member which guides is the stationary member, and the part which is guided is the sliding member.

If a machine member has two groups of bearing surfaces, which is frequently the case, it can be assigned to both classifications. In determining its category, the position of a member whether on top of or underneath another is immaterial, as is the plane of its bearing surfaces. Thus the knee of a milling machine in relation to the column is a sliding member, but in relation to the saddle it is a stationary member.

The form or design of the bearings has no significance in determining the classification of the member. Thus stationary members and sliding members may have either the form of dovetails or square edges.

The bearing surfaces of the stationary member are spoken of generally as Ways, and the bearing surfaces of a sliding member are referred to in a broad sense as slides. We will now describe these terms more specifically using Fig. 17.1 for reference. For example, on the stationary member the bearings which support the sliding member are titled flat ways, and on the sliding member the corresponding bearing surfaces which traverse the aforesaid flat ways are called flat slides.

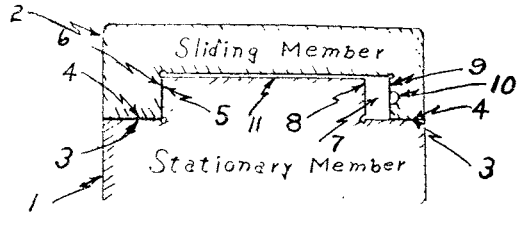


Fig. 17.1(a) Example of square edge type of bearing construction with bearing surfaces identified in list below. (Contact areas between bearing surfaces are double lined)

(1) Stationary member (2) Sliding member (Gib attached) (3) Flat way (4) Flat slide (5) Guiding way (6) Guided slide (7) Gib opening or slot (8) Gib way (9) Gibbed surface (10) Opening for the adjusting screw head of tapered gib piece (11) Clearance

On the stationary member, the bearing which guides is designated the guiding way. The bearing on the sliding member which is in contact with it is termed the guided slide.

NOTE:

The bearing which guides is also known as the positive side. To avoid confusion, the latter term will not be used.

The bearings opposite the guiding way and guided slide receive the gib piece. The designation given these bearings, on what is called the gib side of the castings varies according to whether the gib is fastened, i.e. gibbed to the stationary or to the sliding member. This subject is discussed at length in a later paragraph. Suffice to say, that if, as in the constructions shown in Fig. 17.1(a), the sliding member is gibbed, the surfaces on the gib side of the members would be named as indicated. On the other hand, assuming that the stationary member was gibbed, the designations given the surfaces on the gib side would be as represented in Fig. 17.1(b).

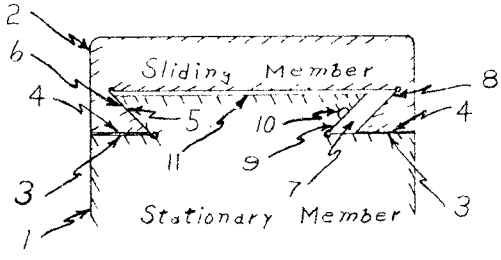


Fig. 17.1(b) Example of dovetail type of bearing construction with bearing surfaces identified in list below. (Contact areas of bearing surfaces are double lined.)

(1) Stationary member (gib attached) (2) Sliding member (3) Flat way (4) Flat slide (5) Guiding way (6) Guided slide (7) Gib opening or slot (8) Gib slide (9) Gibbed surface (10) Opening for adjusting screw head of tapered gib piece (11) Clearance

NOTE:

In the great majority of cases, gibs will be used in conjunction with either dovetails or square edge constructions, less frequently with inverted Vees, and seldom if ever with Vees. Strictly speaking, inverted Vees are not gibbed themselves but usually have an adjacent surface which can be adapted to this purpose. As an example of this, the problem of gibbing a carriage to a lathe bed having inverted Vees is discussed in Sec. 26.46 to which the interested reader is referred.

Sec. 17.2
Preliminaries to Constructing a GIB

The process of producing a gib begins with the careful preparation of the mating machine members which are to be assembled together. All sliding bearings must first be accurately scrape-finished, not only so that they will perform efficiently when placed in service, but also to provide accurate planes from which exact measurements can be made for the gib.

Exclusive of the gibbed surface, which is discussed separately, the requirements for the various bearing surfaces, comprising both male and female dovetails, and also the square edge construction, are as follows:

Sec. 17.3
Requirements of the Bearing Surfaces of the STATIONARY MEMBER

1. Flat ways must be parallel. This condition must be satisfied regardless of which member the gib is fastened to.
2. Gib way (8) Fig. 17.1(a) must be parallel to the guiding way. This is a requirement when the gib is fastened to the sliding member.
3. Gibbed surface (9) Fig. 17.1(b) opposite the guiding way must be treated so as to qualify it for the type of gib to be attached. This is a requirement when the gib is fastened to the stationary member.

Thus the flat ways, the guiding way and the gib way of stationary members are scraped and aligned without regard for the kind of gib piece involved. On the other hand, the treatment given to the gibbed surface will vary according to the type of gib piece which is to be used.

Sec. 17.4
Requirements of the bearing surfaces of the SLIDING MEMBER

1. Flat slides must be fitted to the flat ways i.e. area contact. This provision is always necessary.
2. Guided slide must have full area contact with the guiding way. This is specified under all conditions.
3. Gib slide (8) Fig. 17.1(b) must be parallel to guided slide. This condition is in effect when the gib is fastened to the stationary member.
4. Gibbed surface (9) Fig. 17.1(a) opposite the guided slide must be dealt with in accordance with the kind of gib to be attached. This is a require-

ment when the gib is fastened to the sliding member.

In other words, the flat slides, the guided slide and the gib slide of sliding members are scraped and fitted or aligned as the case requires without consideration for the kind of gib piece involved. On the other hand, the treatment given to the gibbed surface will vary according to the type of gib piece utilized.

Sec. 17.5
Kinds of Gibs

Gibs are made from several kinds of metal, such as cast iron, cold rolled steel, bronze or brass.

Three general forms of gib piece are found in common use on machine tools, namely:

1. The straight flat gib
   (for dovetail and square edge members)
2. The angular flat gib
   (for dovetail members only)
3. The tapered gib
   (for dovetail and square edge members)

Frequently, two or more types of gibs will be used in different places on a machine tool. Sometimes due to machine design two or more gibs are utilized on a single member.

Gibs of all kinds are attachable to either stationary or sliding members. Fig. 17.1(a) shows provision for attaching a gib (tapered) to a sliding member of square edge construction. The location of the hole (10) for the adjusting screw indicates this. In Fig. 17.1(b) the dovetail construction employs a gib (tapered) attached to the stationary member. This is shown by the placement of the opening (10) for the adjusting screw head.

The gib is fitted into the space called the gib opening or gib slot between two mateing members.

To allow the sliding member to traverse freely without looseness or bind, gibs are provided with means for adjustment to the proper tension. The usual method of obtaining the proper sliding tension is by means of screw adjustment.

Sec. 17.6
STRAIGHT FLAT GIBS

Straight flat gibs vary slightly in form when fitted to different types of gib slots. For square edge openings between members flat gibs resemble rectangles when viewed in cross-section. (See Fig. 17.2(a)) When straight flat gibs are inserted in dovetail openings they look like parallelograms if shown in cross-section. (See Fig. 17.2(b))

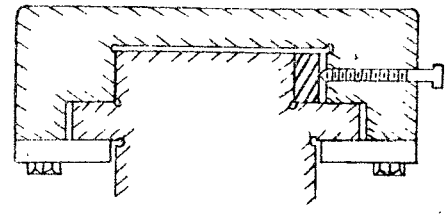


Fig. 17.2(a) Showing gib slot for square edge construction with loosely fitting straight flat gib inserted.

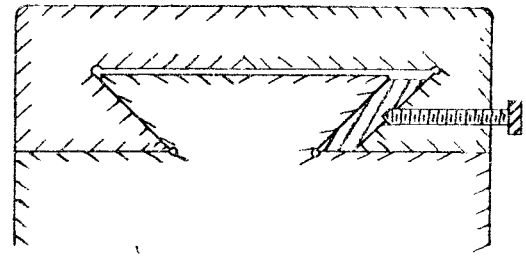


Fig. 17.2(b) Showing gib slot for dovetail type of construction with closely fitting straight flat gib inserted.

Straight flat gibs are further classified according to how they fit the gib slot, namely:

1. Closely fitting straight flat gib. Conditions sometimes require this type. In Fig. 17.2(b) it can be seen that the gib is a close fit in gib opening.
2. Loosely fitting straight flat gib. Conditions sometimes permit this type. The gib piece shown in Fig. 17.2(a) is a loose fit.

There is no essential difference in the method of producing gibs for either type of opening or type of fit.

After the dimensions are ascertained, the straight flat gib is usually ground to size on a surface grinder. Due to the difficulty of maintaining an oil film on a

ground surface, provision ordinarily is made for oil grooves on one side. On the other side small indentations are drilled to receive the ends (tips) of the adjusting screws which will be inserted in the holes drilled and tapped through the gibbed surface of the casting. Tension on these screws adjusts the gib piece to correct sliding pressure.

Sec. 17.7
Closely Fitting Straight Flat Gib

This type demands exact measurements since it must make a close fit in the opening, or gib slot, shown in Fig. 17.3. To be completely satisfactory in this respect, the gib must conform to certain conditions, as follows:

1. The two contact sides (A) and (B) of the gib, shown in Fig. 17.4, must be flat and parallel.

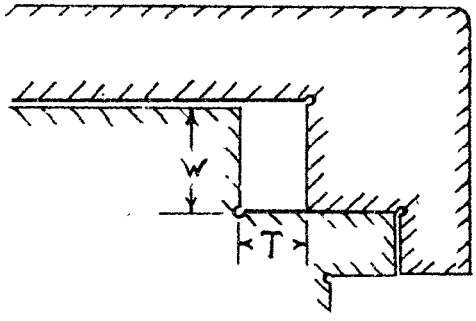


Fig. 17.3(a) Diagrams showing required measurements of gib slot in preparing straight flat gib.

(T) thickness (W) width

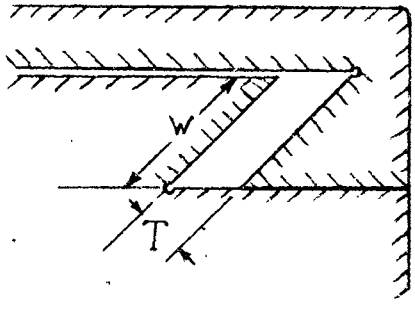


Fig. 17.3(b) Diagrams showing required measurements of gib slot in preparing straight flat gib.

(T) thickness (W) width

2. The thickness (T) of the flat gib is determined by measurement of the gib opening (T) in Fig. 17.3. An allowance of .0005" to .001" is made for oil film.
3. The width (W) of the gib piece should correspond to the width of the gib slide (or gib way.)
4. The length (L) of the gib piece should equal the length of the member to which it is fastened, i.e. gibbed. This may be either the stationary member or the sliding member.

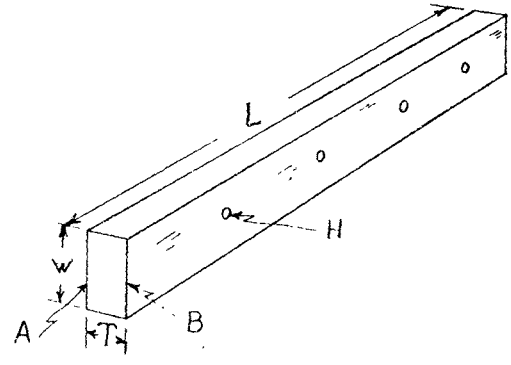


Fig. 17.4(a) Showing required dimension of straight flat gib for square edge openings.

(T) thickness (W) width (L) length (H) small identations which receive screw tips (A) side of gib which contacts gib way or gib slide (B) side of gib which contacts gibbed surface

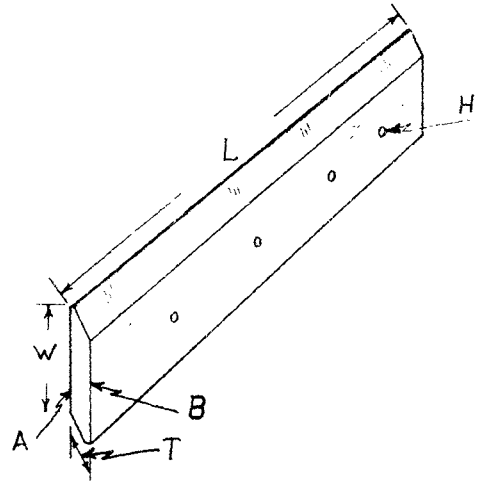


Fig. 17.4(b) Showing required dimensions of straight flat gib for dovetail opening.

(T) thickness (W) width (L) length (H) small indentations for screw tips (A) side of gib which contacts gib way or gib slide (B) side of gib which contacts gibbed surface

5. The side of the gib piece having sliding contact will usually have a surface bearing quality equal to that of the gib slide (or gib way) with whichever it may have a bearing contact.
6. The side of the gib having fixed contact will usually have a surface bearing quality equal to that of the gibbed surface with which it is in contact. As a rule this need be but 4 - 5 bearing spots per square inch. Small indentations are drilled on this side to receive the ends of the adjustment screws.

NOTE:
Since flat gibs are, as a rule, produced by surface grinding, the bearing quality is usually adequate without further treatment.

Sec. 17.8
Necessary Qualifications of a Gibbed Surface Utilizing a CLOSELY FITTING STRAIGHT FLAT GIB

1. The slope of the gibbed surface must equal the slope of the gib way (or gib slide.) See Fig. 17.2(b). This is essential if the parallel sided gib piece is to have area contact on both its sides.
2. The gibbed surface must be scraped parallel to the gib slide or gib way, as the case might be, in order to permit the insertion of the parallel sided gib piece.
3. A surface quality of 4 - 5 bearing spots per square inch is adequate for the gibbed surface.

It can be seen that the preparation of the gibbed surface for the closely fitting straight flat gib necessitates precision scraping and measuring, but a stronger, smoother, operating job justifies the extra effort. The adjusting screws play a minor part in securing rigidity in this type of construction.

Sec. 17.9
Loosely Fitting Straight Flat Gib

The requirements for this type differ somewhat from the closely fitting straight flat gib previously discussed. That they are less stringent can be seen from the specifications enumerated below.

1. The loosely fitting flat gib need have but one truly flat side with adequate bearing quality. The opposite side is not required to be parallel to it. In practice it is usually parallel, though sometimes only rough machined.
2. It is always desirable to make the gib piece the maximum thickness possible to promote rigidity. Yet dimension (T), shown in Fig. 17.4, must be kept sufficiently thin so that the gib will be adaptable to the gib slot and be able to make full area contact with the mateing surface it slides against. This essential condition must be established, otherwise the gib piece cannot perform its proper function. When the gib is unable to move freely to accommodate itself and provide adequate bearing it may be placed under a bending stress when finally adjusted for sliding tension. Should this situation occur, the members will separate and thereby be thrown out of alignment.
3. The width (W) of the gib piece should correspond to the width of the gib slide or gib way, as the case might be.
4. The length of the gib piece should equal the length of the member to which it is attached.
5. The side of the gib piece having sliding contact will usually have a surface bearing quality equal to that of the gib slide or way it bears against. The other side is treated only to the extent of drilling small indentations to receive the tips of the adjustment screws.

Sec. 17.10
Necessary Qualifications of a Gibbed Surface Utilizing a LOOSELY FITTING STRAIGHT FLAT GIB

1. The angle of the gibbed surface is not critical.
2. Parallelism of the gibbed surface with any other surface is not a requirement.
3. The gibbed surface does not have to be flat. Furthermore, no bearing quality is specified, so it need not be scraped. However, if a warp is present it should be removed as it will prevent the utilization of a gib piece of maximum thickness which is always desirable.

Thus we see that when a loosely fitting flat gib is to be used, the gibbed surface

normally needs no preparation whatsoever because it is not in contact with the gib. The rigidity of the assembly is obtained through the small pressure areas provided by the adjusting screws which force the gib into contact with the gib way or the gib slide, as the case might be.

When a greater rigidity is wanted in the assembly, it can be achieved by inserting a thicker gib. In such a case the gibbed surface may have to be machined or scraped somewhat to remove local irregularities, thereby facilitating the admission of a thicker gib piece. However there are no changes called for in the specifications for this surface.

Sec. 17.11
ANGULAR FLAT GIBS

The angular flat gib can be attached only to dovetail designs; it is never applicable to square edges. It may be fastened to either a stationary or sliding member.

This type of gib when viewed in cross-section resembles an isosceles trapezoid, as shown in Fig. 17.5. The form shown in the figure is not to be regarded

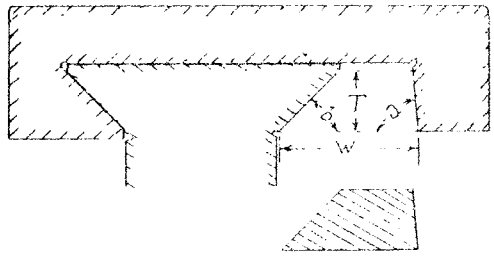


Fig. 17.5 Showing measurements of gib slot for angular flat gib.

(T) thickness (W) width (a) angle (b) angle

as unchangeable. Rather the angle (a) on the fixed side of the gib is variable and may be from 45° up to 90°. The angle (b) may be 30°, 45° or 60° to match the conventional dovetail angle in the member with which it has sliding contact.

Adjustment of this form of gib is accomplished by two or more bolts or studs which draw the gib up against the gibbed surface and gib way (or gib slide). For this purpose bolt holes are drilled through the non-bearing sides of the gib piece, as represented in Fig. 17.6(a).

Fig. 17.6(b) shows the gib fastened to the sliding member with the adjusting bolt underneath. In Fig. 17.7 it is gibbed to

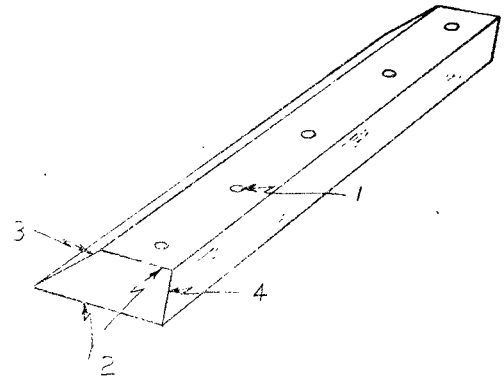


Fig. 17.6(a) View of angular flat gib piece.

(1) Bolt holes (2) Non-bearing sides (3) Side having area contact with gib way (4) Side having area contact with gibbed surface

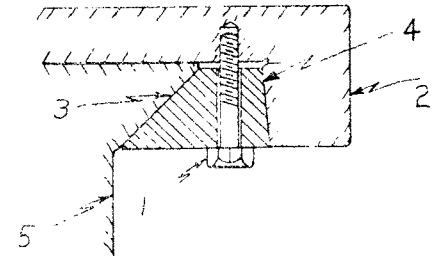


Fig. 17.6(b) View showing angular flat gib assembled.

(1) Adjusting bolt (2) Sliding member (3) Gib way (4) Gibbed surface (5) Stationary member

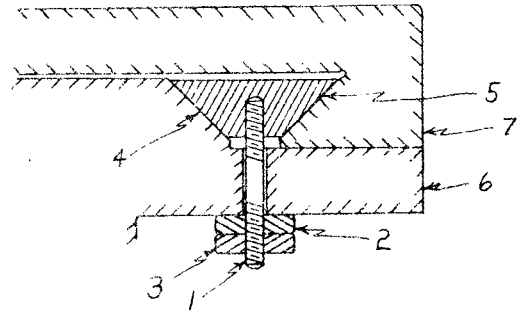


Fig. 17.7 Angular flat gib fastened to stationary member and adjusted from underneath.

(1) Stud (2) Adjusting nut (3) Locking nut (4) Gibbed surface (5) Gib slide (6) Stationary member (7) Sliding member

the stationary member with adjusting nuts underneath. The gib is secured to the sliding member in Fig. 17.8, but in this case the adjusting nuts are on top.

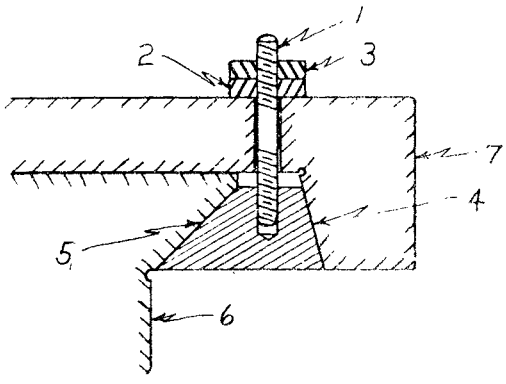


Fig. 17.8 Angular flat gib attached to sliding member and adjusted from above.

(1) Stud (2) Adjusting nut (3) Locking nut (4) Gibbed surface (5) Gib way (6) Stationary member (7) Sliding member

The bearing sides of the angular gib are hand scraped, but to expedite the job, the stock is machined approximately to size before hand operations are undertaken. The following outline indicates the information required before construction can begin.

L Length overall. This is determined by the length of the member to which it is gibbed.
W Width (See Note below)
T Thickness (See Note below)
"a" Angle adjacent to the gibbed surface. (Fig. 17.5)
"b" Angle adjacent to the gib way. (Fig. 17.5)

NOTE:
These measurements for (W) and (T) are taken from the dovetail opening with the sliding member in position on the stationary member as shown in Fig. 17.5. A small addition, say 10 or 15 thousandths of an inch, to the width and thickness of the finish machined gib piece is essential to allow for fitting, which is a spotting and scraping operation.

Sec. 17.12
Preparing the ANGULAR GIB for use with Parallel Surfaces

If the gibbed surface of one member is parallel lengthwise with the gib way (or gib slide) of the other member, as it should be, the angular flat gib is not difficult to spot accurately. The method requires spreading marking compound on both the gibbed surface and gib way (or gib slide). A liberal application is desirable on the first application. (It can be reworked on succeeding cycles.)

To transfer the medium the sliding member is positioned on the stationary member in such a way as to expand the gib slot to its widest extent. The gib piece is now placed in contact with both surfaces above named and rubbed back and forth with about a one inch movement. The value of this spotting lies in its determination of the trend towards the requisite angles. After withdrawing the gib, both sides are scraped as the markings indicate. To speed the work, alternate spottings can be made on a SURFACE PLATE. Spotting and scraping are continued until the gib is completed. This condition is indicated by attaining 4 - 5 bearing spots per square inch on the gibbed or fixed side of the gib piece, and by 10 - 15 bearing spots per square inch on the sliding bearing side, i.e. the side in contact with the gib way (or gib slide). In other words, the angular gib must be fitted to both the gibbed surface of one member and the gib slide (or gib way) of the other member.

Scraping may be continued until the angular gib has a clearance of about 1/64", as shown at (x) in Fig. 17.9(a). This clearance permits limited take-up as wear occurs on the sliding bearings.

Sec. 17.13
Preparing the ANGULAR GIB for use with Non-parallel surfaces

The angular flat gib must sometimes be produced for insertion into members wherein the gibbed surface varies slightly from parallelism lengthwise with the gib way (or gib slide). Obviously, in such a case, the spotting procedure is somewhat more difficult. Since a lengthwise taper between the gibbed surface and the gib

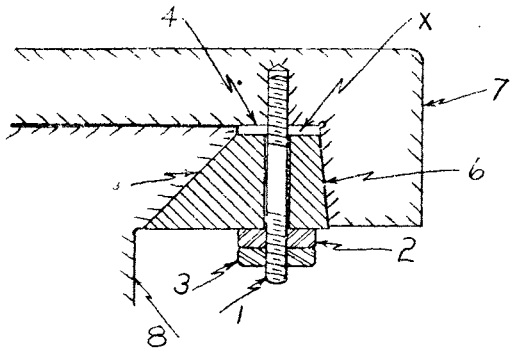


Fig. 17.9(a) Angular flat gib with clearance at (x).
(1) Stud (2) Adjusting tension nut (3) Lock nut
(4) Flat slide (5) Gib way (6) Gibbed surface
(7) Sliding member (8) Stationary member

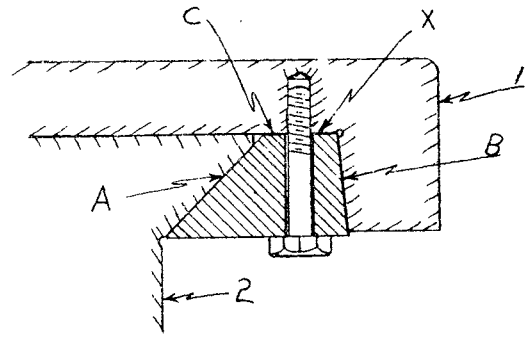


Fig. 17.9(b) Angular flat gib without clearance at (x). (Shows three surface contact)
(A) Gib way (B) Gibbed surface (C) Flat slide
(1) Sliding member (2) Stationary member

way (or gib slide) is now present, false markings would be produced by rubbing the gib piece back and forth to spot it as discussed in the previous section. Consequently, the marking medium must be transferred in another way.

This is accomplished most easily by positioning the gib in the proper relationship to the stationary member and the sliding member, and then applying pressure. The technique is described as follows:

We will use for an example the gib piece shown in Fig. 17.9(a). Screw the studs firmly into the sliding member. Apply marking compound to the gib way and to the gibbed surface. Slip the gib onto the studs to align it properly. By pulling the adjusting nuts up tight, the marking compound will transfer from the spotting surfaces to the gib, and the resultant markings will vary in color, in proportion to the pressure applied to the various parts of the gib. The gib is removed and the coloring of the markings analyzed. Although correct analysis of the markings is important if the angular gib is to be accurately fitted, this aspect of the work is even more important in the preparation of tapered gibs. Consequently, to avoid repetition, this subject is reserved for detailed discussion in Sec. 17.22. This spotting procedure will determine the trend towards achieving the correct angles. The operation is supplemented, as before, with alternate spotting on a SURFACE PLATE to speed the job and to obtain flatness and bearing quality.

To compensate for wear on the sliding bearings a clearance of about 1/64" is provided at (x) on the angular gib, as shown in Fig. 17.9(a). Scraping is continued until this condition prevails.

Sec. 17.14
ANGULAR GIBS without clearance

Some machine designs favor angular gibs fitted to three surfaces. In this case two sides of the angular gib will be fitted to the surfaces previously described. The third side of the gib piece is made to bottom on the member to which it is attached, as represented in Fig. 17.9(b). (In this particular application the gib is fastened to the sliding member.) A study of the figure above mentioned reveals that the gib piece is solidly bolted and there is no provision for flexible adjustment.

A limited adjustment is possible if several layers of thin shims are placed between the sliding member and the gib piece at (x) in Fig. 17.9(b) after the gib is fitted. The advantage of this practice is that as the bearing surfaces wear, shim stock can be removed one layer at a time to take up the slack and thereby maintain fairly satisfactory gib tension.

In the example shown in Fig. 17.9(b) no shims were used, therefore scraping must be continued on surfaces (A), (B) and (C) of the gib piece until full area contact is achieved. This is determined by a uniform coloration and distribution of markings on

each surface. To provide clearance between the stationary and sliding members, surface (A) of the gib is lowered slightly by an additional cycle or two of scraping In this case it will be necessary to utilize a SURFACE PLATE for spotting purposes. This done, the gib is bolted solidly in place. Conditions are now favorable for the proper sliding fit between the members.

To obtain proper fit with angular gibs lacking clearance, surfaces (A), (B), and (C) must be scraped until area contact is achieved on each. Fig. 17.10 shows the

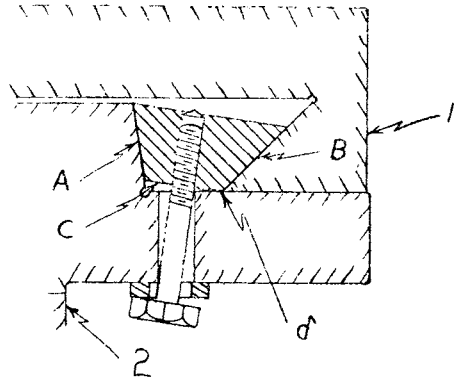


Fig. 17.10 Improperly scraped angular flat gib bottoming at point "d" on flat way.

(A) Side of gib having area contact with gibbed surface (B) Side of gib having area contact with gib slide (C) Side of gib which should have area contact with flat way (1) Sliding member (2) Stationary member

results if surface (C) of the gib piece is not fitted to the surface it bottoms on. The clamping bolts when pulled tight tend to create a greater pressure to one side or the other, depending upon which side of the gib is bottoming. In the present instance this would be point (d). Under these or similar circumstances it is impossible to obtain the correct gib tension.

Sec. 17.15
Essential Qualifications of a GIBBED SURFACE when utilizing an ANGULAR FLAT GIB

1. It should be parallel with the guided slide or with the guiding way, as the case might be.
2. It must be flat.
3. A surface quality of 4 - 5 bearing spots per square inch is required.

Sec. 17.16
The TAPERED GIB PIECE

A tapered gib is a wedge shaped piece of metal having a longitudinal taper. When properly fitted between two mateing members it provides the assembly with maximum rigidity and in this respect is superior to other types of gibs. A tapered gib is essentially an integral part of the members it ties together.

This form of gib can be used with equal facility on either the square edge or dovetail construction.

Tapered gibs are variously shaped. Fig. 17.11 shows a common form for a square edge construction. Sometimes the

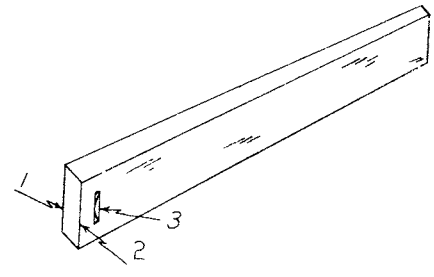


Fig. 17.11 Common form of tapered gib for square edge constructions.

(1) Straight side (2) Tapered side (3) Slot for head of adjusting screw

tapered side of the gib, i.e. the side making contact with the gibbed surface, is modified as shown in Fig. 17.12. The theory underlying this practice is that the two point contact thereby established reduces the tendency of the tapered gib to bow, which could lead to rocking of the member. Occasionally, the mid-section

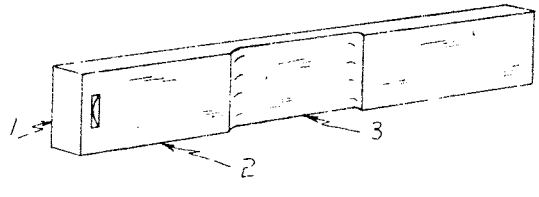


Fig. 17.12 Tapered gib providing two point contact.

(1) Straight side (2) Tapered side (3) Recessed portion

of tapered gibs is deliberately dished out on both sides to provide two point contact for the sliding side also. By thus reducing the area to be scraped, both time and effort are saved, but this plan should be adopted only if the length of the traverse of sliding member is restricted so as not to lose the two point contact. Sometimes the tapered side of the gib is provided with narrow bearing surfaces at top and bottom, as represented in Fig. 17.13.

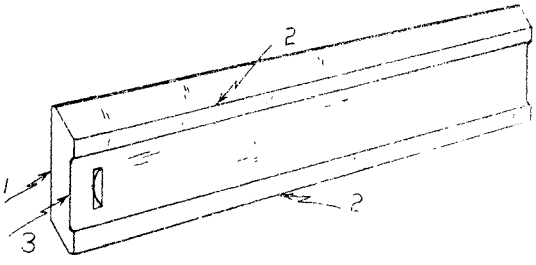


Fig. 17.13 Tapered gib for dovetail constructions showing recessed center.

(1) Straight side (2) Bearing portions of tapered side (3) Recessed center

Tapered gibs are differentiated also by their method of adjustment of which there are three kinds. They are enumerated below but reserved for discussion in a later paragraph:

1. Single end headless type adjustment.
2. Double end headless type adjustment.
3. Head type adjustment.

Adjustment of the tapered gib provides the members with proper sliding pressure. The gib piece is adjusted by screw tension imposed at one or both ends.

In practice, the tapered side of the gib is placed in fixed contact with the gibbed surface of either the sliding or the stationary member. For explanatory purposes, the following text and diagrams illustrate the tapered gib fastened to the sliding component. There would be no essential difference in the form of the tapered gib, or in the method of production, if it were secured instead to the stationary member.

The straight side of a gib has sliding contact with either the gib way of a stationary member or the gib slide of the sliding member. In the following discussion and drawings it will be placed as noted above in sliding contact with the gib way of the stationary member.

When making a tapered gib, the piece of stock is first machined to approximately the correct taper and exact angles. These measurements are computed by reference to the dovetails, or to the square edges, as the case might be. The description which follows deals with dovetails but the procedure would be exactly the same if the tapered gib were fitted to a square edge construction.

Sec. 17.17
Measuring for a TAPERED GIB

The first step in producing a tapered gib is to calculate the taper. As a prelude to this, the two mateing machine members are placed together. The guided slide of the sliding member is pushed by hand tightly against the guiding way of the stationary member. This action widens to its fullest extent the opening for the gib.

The opening or slot between the dovetails, which determines the thickness of the gib, is now measured with a telescopic or ball gage. Measurements in inches are made at both the large and small openings, as shown in Fig. 17.14. Maximum accuracy will be assured if the gage is centrally located in the opening so as to span between the points indicated by the arrow.

Next the length of the sliding member is ascertained. We assume here that the gib is fastened to the sliding member which is usually the case. If the gib were

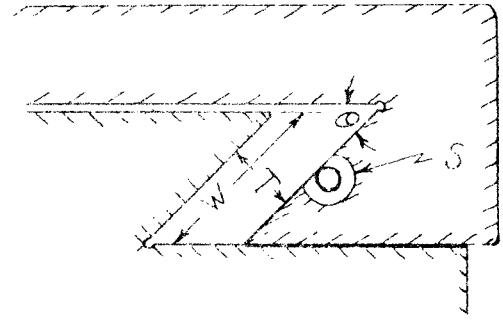


Fig. 17.14(a) Front View of Members. Method of measuring the gib slot at median.

(W) width (T) thickness (S) Recessed hole for head of adjusting screw (θ) Angle

fastened to the stationary member the latter would be measured instead.

Having at hand the necessary data as to thickness and length, the taper per inch can now be computed by the following formula:

FORMULA: To find the TAPER per inch.

$$\text{Taper per inch} = \frac{\text{Large opening (in inches) minus Small opening (in inches)}}{\text{Length of the member to which the gib will be attached (in inches)}}$$

$$\text{Taper per inch} = \frac{t - t'}{L}$$

Sec. 17.18
Supplementary Calculations for TAPERED GIB

In addition to measuring the gib opening and calculating therefrom the taper per inch, an allowance must be made for fitting the gib. Essentially, this involves a modification of two dimensions of the gib, namely the length (L) and the thickness (t). The calculations must be performed and the complete specifications made known before the machine shop can proceed with the construction of the gib piece.

In order to make clear how these two factors will modify the dimensions taken from the dovetail, an example is supplied as follows:

EXAMPLE

Information - obtained from dovetail openings (assumed case) shown in Fig. 17.14.

L -	Length of sliding member	10"
θ -	Angle of dovetail	45°
t -	Thickness of opening (large end)	0.500"
t' -	Thickness of opening (small end)	0.400"
W -	Width of gib opening or slot	2"

Calculation for taper

$$\frac{t - t'}{L} \text{ equals } \frac{.500" - .400"}{10"}$$

or taper per inch = .010"

In this example we decide to have, as a safety factor, an excess length in the machined gib piece of, say, 3". Now we have

Total length of gib piece 10" + 3" = 13"
Total taper in 13" 13" x .010" = .130"

Therefore: Thickness of gib piece --

At small end will be .400"
At large end will be .400" + .130" = .530"

We will now allow ourselves an additional thickness of .020" for purposes of fitting. Consequently, we must again modify the dimensions of the gib piece as follows:

Small end	= .400" + .020" = .420"
Large end	= .530" + .020" = .550"
Length of gib piece	= 13"
Angle of gib piece	= 45°
Width of gib piece	= 2"

This represents the final calculation for the dimensions of the finish machined gib piece. Such measurements are never a matter for guess work but should be closely figured. If the piece is made too thick, extra scraping is necessitated. On the other hand, if the surplus provided is inadequate for good fitting, it results in either an incorrect taper or a poor bearing quality.

Should the length be measured closely, leaving no spare, even a slight scraping error cannot be compensated. Consequently, the operator must either discard the piece and start anew, or be content with a poorly fitting gib.

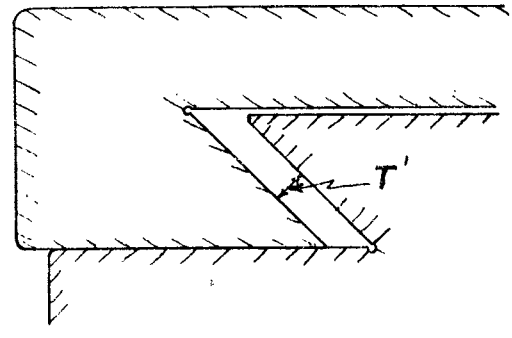


Fig. 17.14(b) Rear View of Members.
(t') thickness

When preparing a tapered gib having the Head Type Adjustment an additional length must be allowed. This portion is then taken into account when calculating the thickness at the large end of the gib.

The thickness of metal allowed for fitting purposes on the average gib should be one or two times the taper per inch. On the other hand, when the taper per inch is small, the surplus retained for fitting purposes should be somewhat more, say three or four times the taper. How much to increase the length and thickness is a question for the individual operator to decide. The decision will be based primarily upon his ability to measure dimensions correctly and scrape expertly.

Sec. 17.19
Checking the TAPERED GIB PIECE before scraping it

After the gib piece is machined to specifications it is given a test preliminary to any scraping. First, it is checked for flatness. If warped, it must be straightened, either by peening or in an arbor press. Then it is examined for size in the following manner:

The small end of the machined gib piece is inserted into the larger or front side of the dovetail opening. Because of the excess metal which was deliberately retained in the example discussed, the gib piece will not slide all the way in. Instead about 5" will protrude if the piece was accurately machined to the specified dimensions. Of this amount two inches will be utilized to obtain the correct taper, adequate bearing surface and exact fit, by means of the scraping process. The balance of the extended portion represents the safety factor.

An adequate allowance is especially necessary if the taper per inch is small, even if the machining has been very precise. This is advisable because the initial scraping cycle may allow a considerable part of the protruding stock to slide into place. After several scraping cycles it may be possible to slide the whole length into the dovetail, but this might occur before it has attained the correct taper or even adequate bearing over its entire surface. In case the total length is insertable before these qualifications are satisfied, the operator is obliged to make up a new gib piece.

It was for the purpose of having a margin of safety that three additional inches were allowed for scraping errors. With this extra length available, there is no cause for concern if the small end of the gib appears at the small dovetail opening before the correct taper and adequate bearing are attained. The three inches, more or less, of gib still protruding from the large dovetail opening can be utilized to compensate for any scraping errors that may be committed.

When the gib is finally completed any portion extending from the small end is cut off. What remains at the large end is cut off, too, after provision is made for an adjusting screw slot.

Sec. 17.20
Spotting and scraping the TAPERED GIB

Two methods of producing the tapered gib are regularly used. The first method described takes longer but is more satisfactory. Proceed as follows:

METHOD NO. 1

The sliding machine member is removed from the stationary member. Marking compound is applied liberally to the dovetail side of each member against which the sides of the gib piece will bear. (In operation the gib has a sliding contact with one member and fixed contact with the other.)

After the marking has been spread evenly on the appropriate dovetail surfaces, the sliding member is replaced on the stationary member. The guided slide of the sliding member is pushed tightly against the guiding way of the stationary member so as to widen the gib slot to its fullest extent.

The gib is inserted by hand until it sticks. Then it is gently tapped in a little farther, using a lead hammer. This procedure will spot the gib. Next it is withdrawn by hand. If it sticks, a brass rod can be inserted in the small opening between the members and tapped with light blows until the gib is freed

When loose, the gib is placed in a vise for scraping, or better yet, laid flat on a work bench. In the latter case the gib can be held immovable by nails driven around

it into the bench.

Metal is removed from those spots where the markings indicate the greatest pressure was imposed. Both sides are scraped one after the other. After the burrs are removed, the gib is wiped clean and re-inserted between the two members. This procedure is repeated as many times as necessary until the gib is finished. By suitably identifying the surfaces, it is possible always to insert the gib so that the tapering side is adjacent to the gibbed surface and the straight side is in contact with the gib way (or slide). The idea underlying this is to prevent a mix-up.

Theoretically, it should be possible to reverse a headless type gib in the opening. Practically speaking, however, the gib way (or gib slide) and the gibbed surface will seldom have exactly the same slope. Hence as a result of the initial spotting and scraping cycles, the gib piece will develop a small transverse taper to match the surfaces it contacts. This will lead to unstabilized markings if, subsequently, the gib is inserted indiscriminately. Sec. 17.27 explains this in greater detail. Obviously, with a head type gib no mistake on this score is likely to be made.

After each spotting the marking medium should be reworked to provide a uniform coating on the dovetail sides. Naturally, this causes the film of compound to become progressively thinner thereby making for greater accuracy in spotting.

In as much as only the inserted portion of the gib is spotted, the trend of the taper is determined by it. The balance of the piece must be scraped in-step so that the surfaces are kept flat at all times. After the trend of the taper becomes apparent, each alternate spotting operation is conducted with a SURFACE PLATE as the spotting tool. Thus during one cycle the inserted part of the gib will be spotted by the dovetail sides. On the following cycle, the full length of the gib should be spotted on a SURFACE PLATE to maintain overall flatness.

Sec. 17.21
Spotting and scraping the TAPERED GIB

METHOD NO. 2

The other method of spotting and scraping a tapered gib is frequently employed. Being faster than the procedure first described, it is popular with many operators. The system is as follows:

1. That side of the gib which has a fixed bearing with the gibbed surface of the member is dealt with first of all. This is intended to be the tapered side. The spotting is done on a SURFACE PLATE. A condition of flatness and a bearing quality of 4 - 5 bearing spots per square inch are requisite before this surface is deemed scrape-finished.

2. Apply marking medium to the dovetail side of that member which has sliding contact with the gib. Place the sliding member on the stationary member so that the dovetail opening is maximum width. Insert the gib, small end first, until it binds. Then tap the large end lightly once or twice with a lead hammer to transfer the medium. Remove the piece by tapping the small end.

3. Scrape the gib where the coloration of the compound indicates the greatest pressures. Continue the routine until the gib is fitted. In short, one surface, the so-called tapered side of the gib, is spotted on a SURFACE PLATE and completed. The other surface of the gib piece is then spotted by inserting it in the usual way into the dovetail opening between the mateing members. This latter operation should not require added comment as it is no different than the method first discussed. (Method NO. 1)

Sec. 17.22
Interpreting the Pressure Markings on a TAPERED GIB

After transferring marking medium to the gib, by either method just described, the operator must be able to interpret the marks correctly. The areas of heavy or light pressure are differentiated by the coloring or shading of the compound. The marks are variously colored and to make the analysis more difficult, not all of them can be taken at face value.

Assuming in our imaginary case that bluing is the medium utilized, the interpretation would follow this line. The dark blue, i.e. (Natural color) of the spotting medium denotes an absence of contact pressure. Areas of the gib marked in this fashion are not to be scraped, as

this coloration indicates the compound was transferred to the gib by accidental brushing against the sides of the dovetail during either insertion or removal and consequently has no importance. Where the color is a light blue, some pressure though not much was applied, so this part of the gib is only lightly scraped. Places where the coloring is almost white have been squeezed more and need to be scraped heavier. Those high spots which appear brown or burned, received the maximum compression and should be scraped the heaviest.

From the foregoing it will be seen that the marks transferred to a gib are the result of pressure. Their significance is similar to the marks formed on ordinary flat surfaces by usual spotting methods. However, the considerable variation in coloring is due to the very heavy force normally applied in spotting a tapered gib as contrasted with the relatively light pressure when spotting other types of work with standard tools.

Sec. 17.23
Preliminaries to Finish Scraping a TAPERED GIB

Referring again to our example shown in Fig. 17.14, we should make certain that the ways of the stationary member are truly parallel before the tapered gib is scrape-finished. To finish the gib piece under the mistaken assumption that the ways are parallel and then discover, following a sliding member test, that this characteristic is lacking, means that the gib must be re-worked. The task involved in correcting the taper could conceivably be so extensive as to destroy much of the bearing surface already developed. Consequently, to avoid the possibility of wasting much time and effort when fitting a tapered gib, it is advisable to stop just short of completion and check the bearing ways of the stationary member for parallelism.

The procedure is to insert the gib in the dovetail opening as far as it will go. Then holding the gib in place with one hand, the sliding member is pushed back and forth with the other hand. If either looseness or binding is noted, it would be a futile effort to scrape-finish the gib. Instead the gib way of the stationary member must be rescraped till parallelism with the guiding way is thought to be achieved. Following this the Sliding Member Test is repeated. If the sliding member moves from end to end of the stationary member, smoothly and without hesitation, parallelism is established. It is now permissible to complete fitting the gib. (See Sliding Member Test Sec. 22.11)

When the gib is attached to a stationary member, the procedure to be followed is comparatively the same as that described above. In short, the work is interrupted before the piece is completely inserted, in order to perform the Sliding Member Test. If either slack or bind is detected in the parts, this deficiency is remedied by scraping the gib slide of the sliding member parallel to the guided slide. Not until the sliding member can move from end to end of the stationary member, smoothly and without looseness, should the gib be scrape-finished.

Sec. 17.24
Finishing the TAPERED GIB

Scraping must continue on the tapered gib piece until three conditions are satisfied, namely:

1. Adequate bearing on both sides of the gib.

The surface of the gib having sliding contact should be flat, with about 10 - 15 bearing spots per square inch uniformly distributed. The other side of the gib having the fixed contact must be flat with about 4 - 5 bearing spots per square inch uniformly distributed.

2. Correct taper.

The taper must be correct the full length of the gib so that the sliding pressure will be evenly distributed. We judge this by a uniform coloration of the markings.

3. Well fitted.

The gib should extend the full length of the dovetail to which it is attached. Usually the small end of the gib will pass through the small opening between the members before the first and second conditions, as given above, are attained. The portion which protrudes serves no useful purpose and is cut off flush with

the opening. Whatever surplus length remains at the large opening is also cut off to the correct size. Before doing so, however, the piece is slotted in a milling machine and fitted with an adjusting screw. This completes the gib.

The critical reader will have noted that we say, "Cut off the superfluous length of the gib, at the large end, after providing for a slot." This depends upon the type of gib adjustment. In case either a single or double headless type gib is used, the instructions in Sec. 17.25 will help to locate the slot.

If the Head Type of gib adjustment is selected, several additional inches of stock at the large end of the gib will be required to provide the necessary adjustment. This must be anticipated when designing the gib.

Sec. 17.25
LOCATING the ADJUSTING SCREW SLOT in a TAPERED GIB

(For single or double headless type tapered gibs)

1. Adjust the sliding member flush with the stationary member.
2. Force the gib into the dovetail opening until it is snug. Then scribe a line on the gib to indicate the length of the inserted portion. Now withdraw the gib.
3. Insert and thread the adjusting screw all the way into its tapped hole. Measure the distance (X) from the dovetail opening to the head of the screw, as shown in Fig. 17.15. Next back the screw all the way out, except for several turns, and measure the distance (Y) from the dovetail opening to the head of the screw. By doing this we have learned the distance the screw can travel. With a well fitted gib allow approximately 1/2 the travel of the screw for adjustment of the gib.
4. Measure out this distance, say 1/2 the screw travel, from the scribed line on the gib, towards either the thin end of the gib, as in Fig. 17.16(a), or the thick end of the gib, as in Fig. 17.16(b), depending on whether the head of the adjusting screw is located inside the casting or outside, respectively. This will indicate the point where the adjustment slot should be cut. Incidentally, this slot will always be on the tapered side of the gib piece, i.e. the side in contact with the gibbed surface of the member.
5. Cut the slot. Having allowed several extra inches of length on the gib, the

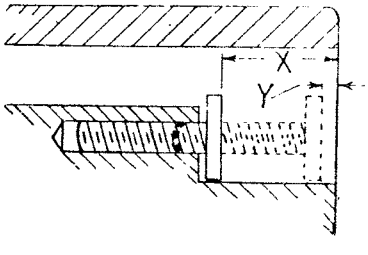


Fig. 17.15 Method of locating position for adjusting screw slot for single or double headless type tapered gibs.

(X) Distance from dovetail opening to head of screw run in (Y) Distance from dovetail opening to head of screw backed out

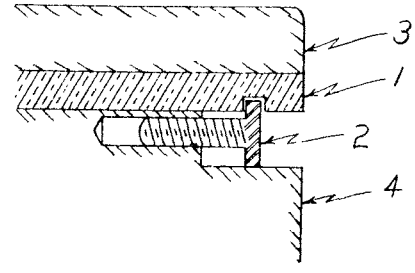


Fig. 17.16(a) Longitudinal sectional view of adjusting screw positioned in slot of a tapered gib located inside casting.

(1) Gib (2) Adjusting screw (3) Sliding member (4) Stationary member

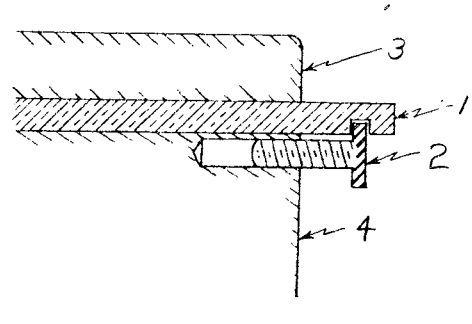


Fig. 17.16(b) Longitudinal sectional view of adjusting screw positioned in slot of a tapered gib located outside of casting.

(1) Gib (2) Adjusting screw (3) Sliding member (4) Stationary member

operator should have ample stock remaining to position the slot correctly. After the slot is formed, the gib is cut off about 1/2" from the slot towards the thick end, or at the original scribed line in case the adjusting screw is located inside the casting. Fig. 17.16(a) and Fig. 17.16(b) merit some close study as they are representative of the single headless type tapered gib fastened to the stationary member.

6. With the double headless type adjustment, a circular groove (a) Fig. 17.17,

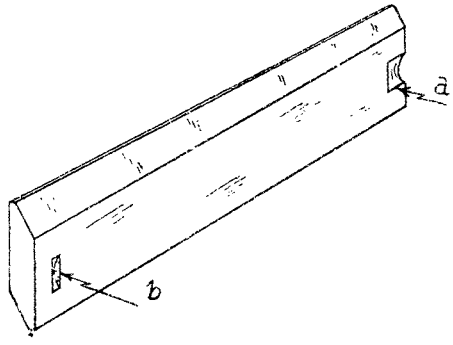


Fig. 17.17 Tapered gib piece prepared for double headless type of adjustment. A circular groove (a) is sometimes cut in the small end to receive the locking screw head which prevents transverse slipping of gib. The circular slot (b) receives the adjusting screw head.

is sometimes cut in the tapered side of the gib piece at the small end. Its function is to receive the round locking screw head which keeps the gib from slipping upward or downward at this end. This groove is eliminated from other designs. In all cases, however, a circular slot (b) is cut at the large end of the tapered gib to receive the round adjusting screw head. The method of measuring to locate the proper position for the slot has been explained in the several preceding paragraphs. Fig. 17.18 illustrates the double headless type gib without a circular groove for the locking screw.

Except for saying that the milling cutter used to form the slot should match the thickness and diameter of the adjusting screw rim, we will not discuss the actual set up and machining operation as these matters are beyond the scope of this book.

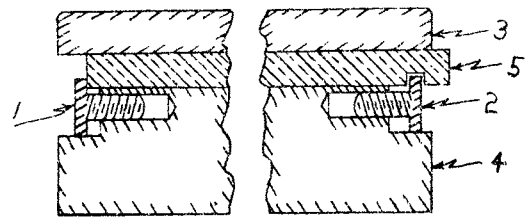


Fig. 17.18 Diagram showing longitudinal sectional view of double headless type tapered gib with adjusting screw tightened to working pressure and locking screw of type not requiring groove holding small end of gib.

(1) Locking screw (2) Adjusting screw (3) Sliding member (4) Stationary member (5) Gib piece

Sec. 17.26
Specifications for the HEAD TYPE TAPERED GIB

When producing a tapered gib with head type adjustment, the measurement formula previously given in Sec. 17.18 is satisfactory except for a few slight modifications, to wit:

1. The length, width and thickness of the gib head (4) shown in Fig. 17.19 must be determined. These dimensions are optional with the operator.
2. The overall length of a tapered gib designed for the head type adjustment is calculated by adding to the length of the dovetail member the thickness of the head, plus the allowance for gib adjustment. Anything more than this

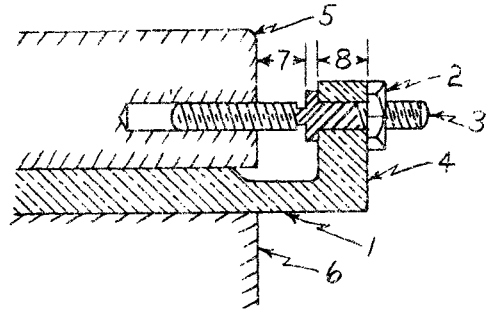


Fig. 17.19 Longtudinal sectional view of head type tapered gib piece secured (gibbed) to sliding member.

(1) Tapered gib piece (2) Locking nut (3) Adjusting screw (4) Gib head (5) Gibbed member (sliding) (6) Stationary member (7) Maximum gib adjustment (8) Thickness of gib head

is superfluous. To allow for machining or scraping errors, it is advisable to increase the thickness dimension by multiplying the taper per inch by a factor of 2 or 3 as suggested previously.

When the operator spots and scrapes a tapered gib having the head type adjustment, the instructions given for other types of adjustment hold true in the main. The only thing to be added is that scraping must continue until the head of the gib piece is close enough to the member to insert the adjusting screw the necessary distance.

Sec. 17.27
Special problems involving Transverse Taper

(The following discussion, while it pertains specifically to tapered gibs fitted to dovetails, applies with equal force to tapered gibs fitted to square edges.)

As we have shown, producing a tapered gib is a somewhat complex operation that is considerably more difficult than the preparation of a flat gib. In the first place, it must have a taper running the length of the piece. Secondly, a cross-section of a tapered gib reveals that it has, or should have, two pairs of oppositely equal angles. This is the proper construction for a tapered gib, but it is realized only if the dovetails it is designed to hold together have matching angles. When the dovetails are properly constructed, it is feasible to produce a properly formed tapered gib. If viewed in cross-section, this is a parallelogram, as shown in Fig. 17.20(a).

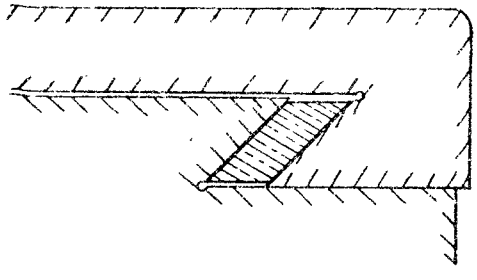


Fig. 17.20(a) View showing correctly formed dovetails, opposite sides parallel. Tapered gib piece is then symmetrical.

Circumstances sometimes demand the construction of a tapered gib to match dovetails having different angles. In other words, the scraping operator is often obliged to make the best of a bad situation. Consequently, when dovetails having a difference in angles are encountered, the tapered gib must be made to fit these diverging angles so that the members will be firmly fastened together.

This type of tapered gib is non-symmetrical and it has a transverse taper, as shown in Fig. 17.20(b) and Fig. 17.20(c). The principal fault of this construction is its tendency to slide away from the applied pressure. This would be towards surface (x) in Fig. 17.20(b). When this occurs the members will loosen. The gib shown in Fig. 17.20(c) would tend to work toward surface (y).

It is extremely difficult to produce a tapered gib of assorted angles. If, however, circumstances necessitate such an undertaking, the most satisfactory results can be obtained by the following method.

Measure the large dovetail opening and

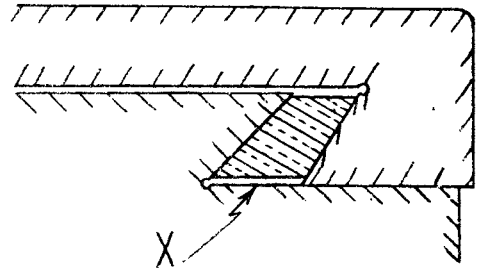


Fig. 17.20(b) View showing improperly formed dovetails, opposite sides diverge. Tapered gib piece is not symmetrical.

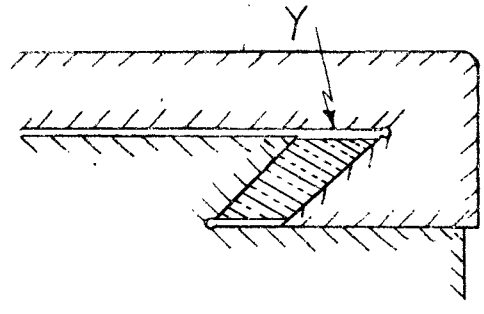


Fig. 17.20(c) View showing improperly formed dovetails. Taper of dovetail sides necessitates a transverse taper in gib piece.

determine which is wider, the top or bottom. In Fig. 17.20(b) the bottom is wider, whereas in Fig. 17.20(c) it is the top which is wider.

Next insert the gib piece for spotting. The important thing to remember when doing this is always to press it toward either the surface indicated as (X) in Fig. 17.20(b) or toward the surface denoted as (Y) in Fig. 17.20(c), whichever is wider. While pressing the gib by hand against the wider surface it is struck lightly at the large end with a lead hammer until it sticks. The gib piece must be held and tapped in this manner during every insertion for spotting purposes until it is fitted.

If this instruction is ignored, and the recommended routine omitted, the operator will soon discover that spotting is not producing stabilized markings, and no positive results will be forthcoming. See Sec. 11.3 on Stabilized Conditions. Should the gib be inserted in a haphazard fashion, it may each time assume a different position, with one or the other end canted up or down. Stabilized markings under these circumstances are virtually impossible to obtain.

Sec. 17.28
Alternative Measurement for a TAPERED GIB

Even if the scraping operator does not perform the actual machine work on the gib piece, he will at least be obliged to specify its dimensions, including the taper. One suggested plan of measurement for a tapered gib was outlined in Sec. 17.17, but if it isn't feasible to place the two bearing members together and calculate the taper with the formula there discussed, the following method will do very well.

The first step is to make a jig similar to the one shown in Fig. 17.21 and mount a DIAL INDICATOR on it. Then a penciled line is drawn on the flat way. After measuring off 12" or multiples thereof, another line is drawn. The contact point of the DIAL is placed at the starting line and moved to the stop line. While doing this the legs of the jig must be held against the angular way and flat during the complete movement. A record is kept

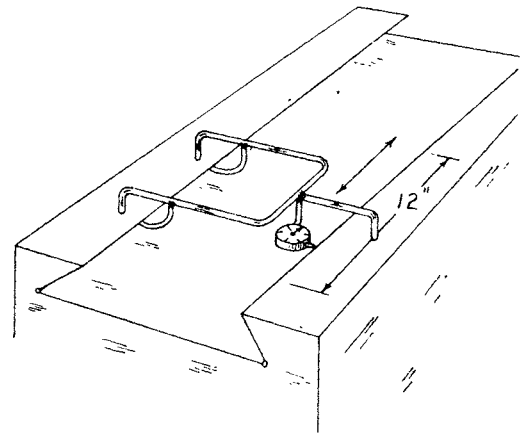


Fig. 17.21 Method of using INDICATOR jig and DIAL INDICATOR to measure the taper of a dovetail.

of the DIAL reading which will express the taper in thousandths of an inch per foot.

The average DIAL INDICATOR will allow slightly more than two complete revolutions of the pointer, or a total exceeding 0.20". This swing is sufficient to register the taper for most gibs.

Sec. 17.29
Utilization of the OLD TAPERED GIB

To save both time and effort when reconditioning a machine tool, and thereby lower costs, the tapered gib accompanying the part is utilized whenever possible. It will most likely be kept in those cases where only a small quantity of metal was removed from the ways and slides of those members which influence the size of the gib slot or opening. In other words, if it is judged that the gib will have sufficient surplus length after fitting to permit a reasonable adjustment, it can be retained and used again.

Since the old gib is already equipped with an adjusting screw and slot, spotting operations to locate worn areas on the gib are much simplified. To take advantage of this, it is suggested that the adjusting screw be inserted into the slot to provide the necessary pressure for spotting. The screw will also expedite the removal of the gib piece in order to scrape it.

Sec. 17.30
Preventing a Warp

To reduce the likelihood of warping a tapered gib during production, the most efficacious measure that can be taken is careful handling. If the operator will work cautiously from the very start of the job, beginning with the initial insertion of the gib piece into the gib slot, much can be done to prevent the development of this fault.

The gib piece should be inserted by hand till it binds, then tapped lightly with a soft lead hammer. Equal care should be taken withdrawing it, so that the piece is subjected to the minimum amount of shock. Essentially, the chief factor causing warping is haste. It is trying to insert too much of the gib piece into the gib slot, too fast, that warps the material and necessitates doing the job over.

After withdrawing the gib, both sides should be dealt with simultaneously, that is in step. One side is scraped to the taper, while the other side is being scraped straight. If this method is followed, a warp can be corrected as it develops. This procedure is preferred to scraping one surface to completion before starting the other because a warp is then more difficult to eliminate.

Sec. 17.31
Reducing a Warp

In the process of being tapped into place with a hammer, or forced into position by screw pressure, the tapered gib is often permanently warped, that is, bent at an angle, or bowed. This warping will be readily apparent when it is rubbed on a SURFACE PLATE for alternate spottings.

Only careful workmanship can prevent such damage. However, should one of these distressing mishaps occur, its effect can be minimized by appropriate steps. The selection of remedial measures depends on the kind of warp, its magnitude, and the thickness and strength of the gib piece. When the warp is definite, with a measurable angle, it may be straightened, either by peening or in an arbor press. Then if there is sufficient metal, spotting and scraping can be resumed in the usual manner. Sometimes the excess of metal remaining on the tapered gib will not be enough to allow the removal of all traces of the warping and of the efforts to straighten it. Rather than discard the tapered gib piece and start over, there is a fair chance of salvaging it if circumstances will permit the scraper to produce one having a somewhat battered appearance.

The first step is to concentrate the scraping effort on producing a good bearing on the face which has a sliding contact. Then the gib piece is scraped to the correct taper by removing the metal from the side having fixed contact. Even though a few low places remain on the latter side, the gib when completed will probably be satisfactory, unless the depressions are too large and are positioned near the ends which would tend to instability, i.e./"rock" in the sliding member.

When the gib piece is thin and the defect is a uniform though not excessive bow, a satisfactory fit can be obtained by the following method:

The tapered gib is inserted into the gib slot either by tapping it in or by turning the adjusting screw. The pressure applied in this spotting process straightens out the gib sufficiently so that it will be marked correctly. Guided by the coloration of the markings, the gib piece is scraped and a correct taper is generated. Although the warp is not eliminated by this technique, the gib piece will, nonetheless, function properly when inserted and held in place.

The above procedure cannot be applied when the gib is warped at a pronounced angle, or when the gib piece is thick or is excessively bowed. In such instances the defect must be removed before spotting. Otherwise, the pressure of the gib as it is forced into a straight line by the dovetail sides will produce markings of its own. Unfortunately, these would be indistinguishable from the true marks produced in spotting to obtain the proper taper.

Sec. 17.32
Gib Adjustment

All machines having sliding members which are gibbed require adjustment from time to time as parts and bearing surfaces wear. For this purpose flat bearings are provided with gibs. Adjustments, when required, should be promptly made lest

the accuracy of the machine be impaired. As wear increases, the lost motion becomes greater, causing affected parts and bearing surfaces to deteriorate even more rapidly. It is essential, therefore, to make examinations from time to time, so that the accuracy of a machine can be maintained and its working life prolonged. Regular and diligent inspections, because they are an important feature of the "stitch in time" principle, will help to lower maintenance costs.

All types of gibs have some method of easy adjustment to provide the correct sliding pressure of one member upon another member. Flat gibs, for example, are usually equipped with bolts or studs with locking nuts, which are adjustable to supply a proper tension and maintain it. (See Fig. 17.2 and Fig. 17.7) Since the technique is elementary it need not be further amplified.

Tapered gibs, on the other hand, merit some further comment as they are adjustable from either one end or both ends. There are three main types of adjustment for tapered gibs, namely:

1. The single headless type gib. It adjusts from a single end.
2. The double headless type gib. This form adjusts from one end and locks from the other.
3. The head type gib. It adjusts and locks from one end.

(One CAUTION applies to all types of gibs. DO NOT ADJUST THE GIBS TOO TIGHTLY. Excessive pressure squeezes out the oil film thereby causing scoring and untimely wear.)

Sec. 17.33
Adjusting the SINGLE HEADLESS TYPE tapered gib for wear or sliding pressure

(Fig. 17.16 shows the design referred to.)

1. Adjustment is made by turning the screw in a clockwise direction until the gib is tight. Then back the screw away until the slide moves freely but without shake.

Sec. 17.34
Adjusting the DOUBLE HEADLESS TYPE of tapered gib for wear or sliding pressure

1. The adjustment of the double headless type tapered gib (Fig. 17.18) is similar to that of the single headless type gib, with this difference: The double headless type employs two screws, one at each end. The first screw adjusts the gib and the other screw locks it in position. Thus the gib is easier to keep in place. The mechanical arrangements shown in Fig. 17.16 and Fig. 17.18 may be used to adapt the tapered gib to either type of opening, i.e. dovetail or square edge.

Sec. 17.35
Adjusting the HEAD TYPE tapered gib for wear or sliding pressure

1. Loosen the locking nut (2) shown in Fig. 17.19.
2. Revolve the screw (3) in a clockwise direction for two or three revolutions.
3. Turn the locking nut (2) in a clockwise direction until the gib is tight, then back it away two or three turns.
4. Turn screw (3) in a counter-clockwise direction until the flange touches the gib head, then continue in the same direction about one turn more. This action provides the proper sliding tension.
5. Lock the gib (and screw) in position by tightening nut (2).

Sec. 17.36
SLIDING PRESSURE

This term refers to a condition of tension between the sliding bearing surfaces of two mateing machine members. The tension is supplied by the adjustment of a gib piece which may be of a straight flat, angular flat, or tapered construction. By tightening the adjusting screws of the gib, the sliding pressure between the affected members will be increased.

In adjusting a gib piece for sliding pressure, the operator attempts to reconcile two conflicting and diametrically opposed conditions, namely:

1. Rigidity of the members.

This characteristic is desirable

because it reduces side-play between the members. Thus a tight gib adjustment would tend to induce truer machining by the cutting tool. The theoretical improvement in accuracy of output, however, is modified by other factors. For instance, tight sliding pressure causes the sliding member to traverse with hesitation and chatter may develop. Another unfavorable reaction is that the bearing surfaces themselves deteriorate faster when tightly squeezed because this thins the oil film. It is frequently accompanied by scoring.

2. Freedom of movement.

Loose adjustments permitting this distinguishing action make for a steady, even traverse, without bind, hesitation, or skip. It facilitates the lubrication of the bearings and prevents scoring due to inadequate oil film. Accuracy, however, is impaired when the gib is loosely adjusted and allows side play between members.

Since it is obvious that neither of these conditions is unqualifiedly favorable, it will be necessary to effect a compromise. The proper adjustment for correct sliding pressure varies for each gib. Among the factors to be considered are the type of members being connected, the frequency of use, the rapidity of traverse, the type of oil and its temperature and viscosity. Another important consideration is the condition of the bearing surface. A higher quality of bearing, evidenced by more bearing spots per square inch, calls for less tension on the gib piece, and vice versa. Allowance also must be made for the degree of deviation from parallelism between the ways (or slides as the case might be.) The straighter the ways (or slides) the more the tension can be increased with safety because there will be less chance of binding. Other matters to be studied are the type of metal, the depth of cut, the kind of feed, whether screw, geared or hydraulic, and the travel in feet per minute.

Speaking generally, there are three ways to judge whether the gib binding two machine members is adjusted to the correct sliding pressure. Each method can be applied by moving the sliding member back and forth meanwhile testing as follows:

1. By the feel of the hand which is a convenient and sensitive gage. This method is preferred.
2. By hand, but through a mechanical advantage, such as a screw or gearing. Here the hand is in a position to judge the amount of muscular power required to traverse the member, though not so accurately because of its indirect application. Large heavy members must be moved this way.
3. By power drive. In this application the hand laid on the mechanically driven member can feel the smoothness or hesitation of the sliding action. The ear is able to distinguish between the sound of a member which is moving freely and one which is being forced. Visual inspection can determine by the appearance of the oil film on the stationary bearing surfaces, after the sliding member has traversed them, whether pressure was excessive. Finally, the smoothness of finish that the cutting tool imparts to the machined stock is a most convincing test.

The reason that gib adjustment has been discussed at such length is that, while more immediately a concern of the machine adjuster, it is also a matter of interest to the scraper. In tracing down the cause of inaccurate or otherwise unsatisfactory output of a machine tool, the adjustment and condition of all gibs should receive careful consideration.

Chapter 18

GROOVES

This chapter is devoted mainly to a discussion of clearance grooves and to a consideration of various machine designs which require them. Although not directly related to the general subject, the chapter is concluded with a brief mention of Oil Grooves.

Sec. 18.1
Clearance Grooves

One of the less prominent, though by no means unimportant, features seen on machine members are clearance grooves. A clearance groove is simply a channel that is cut, filed, machined, or ground into a square edge or dovetail. The purpose of the groove is to accomodate the edge of a SURFACE PLATE or other spotting template when applying marking compound to the bearing surface. It makes possible a 100% coverage of the surface when spotting. It has one other function, namely, to provide the blade of the scraping tool with clearance room when scraping these bearing surfaces. When the scraper blade can pass over the edge of the groove, it cuts more cleanly and the tendency to form chatter marks on the bearing being scraped is thereby lessened.

By reason of these advantages, a clearance groove is incorporated into the design of nearly all slides and ways. When a scraper must work into a dovetail or against a square edge lacking this feature, the difficulties are considerably increased.

Sec. 18.2
Testing the Clearance of the Groove.

Before commencing scraping operations on a machine part, it is good practice to test the groove for clearance. Proceed as follows:

1. Place the spotting tool on the bearing surface thus in effect forming a tunnel in combination with the groove.
2. Position a bright electric light at one end of the tunnel.
3. Sight from the other end of the tunnel toward the light.
4. If the light is clearly visible, the groove is adequate in depth and the spotting tool may be used with safety.
5. In case the light is not seen clearly, the groove should be deepened with either a groove cutter, hacksaw blade, or knife edge file.

Sec. 18.3
Adequacy of Clearance Grooves

Reconditioning a worn machine is a problem vastly different from manufacturing a new one. Usually the slides and ways are badly deteriorated and considerable metal must be scraped away to produce a flat surface. Ordinarily, special spotting templates are not available and it is necessary to rescrape the machine making the best use of whatever shop tools are on hand. Their suitability will determine to a large extent whether a fillet or a sharp corner can be retained or whether a groove must be cut. It is also a factor in deciding if the design, form, size or depth of existing grooves must be modified.

Fig. 18.1 represents a groove that is too shallow for the knife-edge of the ANGL STRAIGHT EDGE being employed. The inadequacy of the groove will cause the tool to bottom and will thereby prevent stabilized markings on the angular slide. Such a groove would, however, be adequate for spotting the flat slide adjacent. To spot both surfaces successfully with a knife-edge type of tool, deepening the groove is a necessary first step.

Fig. 18.2 shows a member featured by a groove that is amply deep but is too narrow to admit the available tool which is represented as a blunt or stub edge, ANGLE STRAIGHT EDGE. It can be seen

that a part of the dovetail angular way, as well as a portion of the flat way of the dovetail would not be spotted by the tool. This kind of groove requires widening before the blunt edge ANGLE STRAIGHT EDGE can be expected to spot accurately.

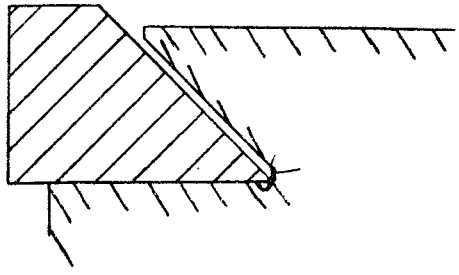


Fig. 18.1 View showing that groove of inadequate depth prevents ANGLE STRAIGHT EDGE from making proper contact with dovetail.

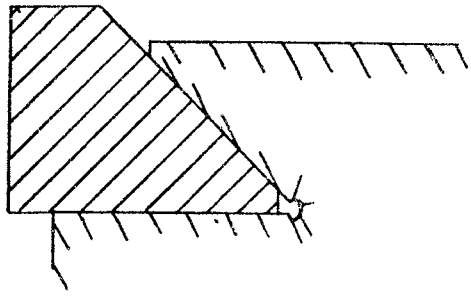


Fig. 18.2 Diagram of well formed groove which is nonetheless inadequate due to the form (stub edge) of the ANGLE STRAIGHT EDGE.

Fig. 18.3 illustrates a groove which is adequate in all respects for the shape of the spotting tool. It is obvious that one should not alter the shape of shop tools to accomodate them to some casual job. It is far better to widen or deepen the existing grooves, or even cut new ones when none are present in a machine member, than to change the form of the spotting tools.

Sec. 18.4
Bottoming the Tool

When a groove is incorrectly proportioned or is too shallow to receive the available ANGLE STRAIGHT EDGE, there are two possible solutions. The most obvious one is to enlarge the groove to adequate size.

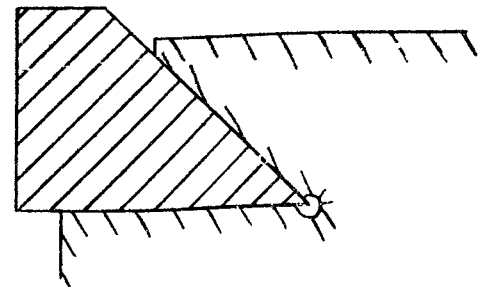


Fig. 18.3 Showing a groove correctly formed and of adequate depth for the inserted tool.

The other solution seeks to avoid expanding the groove because to do so reduces somewhat the area of the adjacent bearing surfaces. Furthermore, an enlarged groove may be unsightly and consequently undesirable. Then too, widening the groove requires additional work and often time is short. It is necessary, therefore, to devise a means of spotting the dovetail surface accurately, taking the groove as it comes.

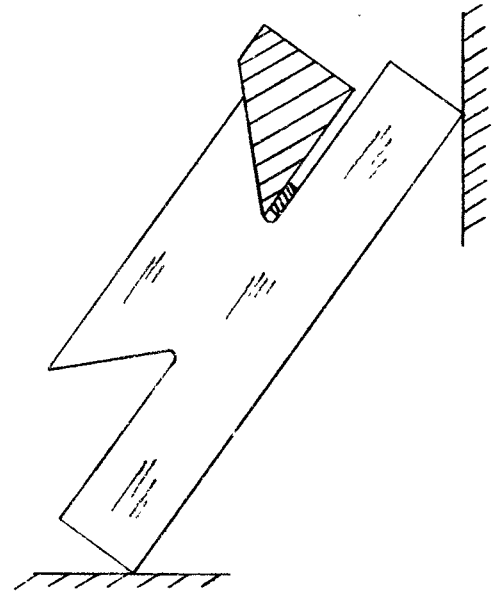


Fig. 18.4(a) Utilizing shim stock to support tool when spotting dovetail having a fillet.

Fig. 18.4b illustrates a simple procedure which can be adopted to solve such a problem.

In this method a thin feeler gage or a piece of thin shim stock, about 1" x 3", is placed at each end of the flat way under-

neath the STRAIGHT EDGE. The pieces at each extremity are of equal thickness.

When selecting the feelers, consideration must be given to the depth of the groove. A thicker piece of shim stock is called for when the groove is very shallow, than when it is moderately deep.

The thickness of the feeler or shim stock should be sufficient to elevate the tool to provide clearance room at the bottom. This allows the weight of the ANGLE STRAIGHT EDGE to be carried at the junction of the groove so that stabilized spotting is possible.

Incidentally, this procedure may also be adopted when a fillet is encountered on a machine member. Fig. 18.4a illustrates how the thickness of the feeler gage or shim stock supports the tool and prevents it from touching the fillet.

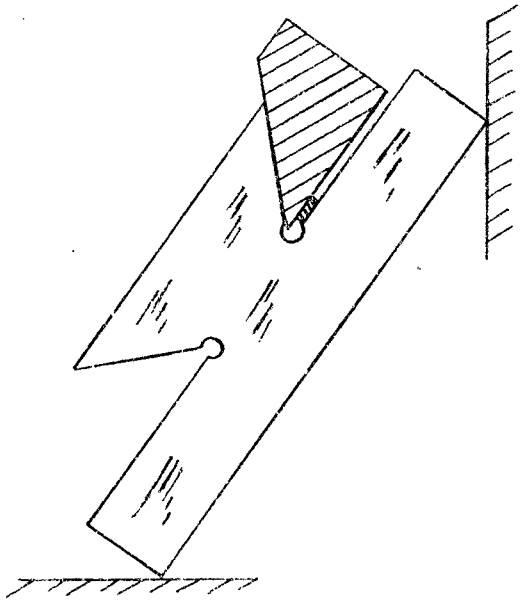


Fig. 18.4(b) Using shim stock to compensate for a groove unsuited to the available tool.

The reason that this system works successfully is that by canting the machine member the weight of the STRAIGHT EDGE is balanced equally against the angular way of the dovetail and against the feeler gage. Conditions then are most favorable for stabilized markings and the tool will spot the dovetail angular way correctly. Substantially, what this procedure does is increase the effective depth of the groove without physically altering it. As for the flat way it can be spotted most effectively if it is positioned horizontally. To facilitate this work the use of a tilting turn table is recommended. Consult Sec. 4.6.

A word of caution is in order regarding the use of shim stock. This material comes in coils and seems to retain a slight curvature even when presumably rolled flat and cut in short lengths. The tendency to curl is more noticeable in the thicker calipers. It is advisable, therefore, to avoid using the latter because the weight of the STRAIGHT EDGE may not be sufficient to flatten the material against the machined surface. It is the better practice to utilize two or more thin pieces when additional thickness is required. A helper may assist by holding the shim stock in position while the operator manipulates the tool.

Sec. 18.5
Clearance Grooves on Square Edges

Although more emphasis has been placed on the necessity of having properly proportioned, correctly sized grooves when applying an ANGLE STRAIGHT EDGE to dovetails, it was not meant to imply that the provision of suitable grooves for square edges was not equally important. With the latter it is customary to use either a SURFACE PLATE or a conventional STRAIGHT EDGE for reverse spotting. When a correct groove is cut, these spotting tools are then capable of applying marking compound all the way into the corner. Similarly during the scraping process, the blade of the scraping tool will have sufficient room to cut flush with the vertical wall, leaving no fillet. (See Fig. 18.5)

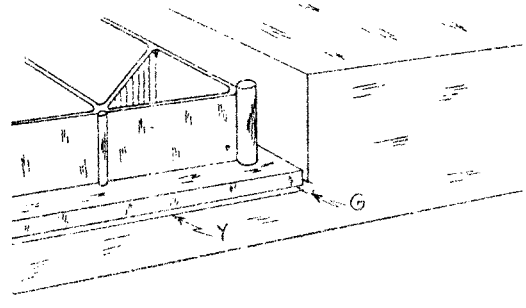


Fig. 18.5 View showing how a properly designed groove (g) facilitates spotting the entire bearing surface (Y).

Sec. 18.6
Clearance Grooves on V-ways.

The oil channel machined at the bottom of V-ways, illustrated in Fig. 29.4, serves the same purpose as a clearance groove. It allows the scraping tool to pass cleanly over the bearing surface thereby preventing chatter marks. Furthermore, it facilitates accurate spotting.

Sec. 18.7
Fillet

Another design feature that is a source of trouble to the scraper is the fillet. This is a concave form of an inside corner. It is produced when material is left in the corner during machining.

A comparison of Fig. 18.5 and Fig. 18.6 will indicate the difference between a groove and a fillet.

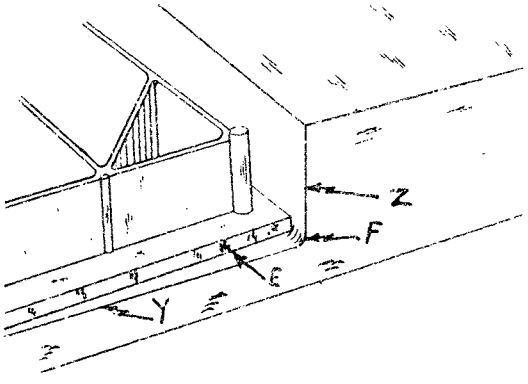


Fig. 18.6 Diagram showing effect of fillet (F) on bearing surface (Y) when tool is bucked against bearing surface (Z). Contact is made only at (F) and (E).

(Z) Vertical side wall (Y) Flat way being spotted
(F) Fillet (E) Edge of bearing surface

Fig. 18.6 also illustrates the scraping difficulties inherent in a design having a fillet. It is obvious that if the SURFACE PLATE shown is pushed against the side (Z), then surface (Y) will not be spotted except at the fillet (F) and at the edge (E). But since surface (Y) cannot be spotted accurately by the tool when it is riding on only two points, (F) and (E), it is necessary to draw back the tool from the side (Z). The question now is "How far should it be withdrawn?"

It can be seen that it is impossible to determine at exactly what point on the surface (Y) that the radius of the fillet begins. Therefore, to play it safe, the operator will be obliged to lay his SURFACE PLATE farther from the fillet area for each new spotting cycle. And since, normally, only the indicated markings are removed, the operator will not scrape into the fillet. Consequently, the fillet is constantly enlarged while the bearing surface (Y) decreases proportionately with each scraping cycle.

The solution to the problem is found by providing a positive stop for the SURFACE PLATE, such as a straight flat board. (See Fig. 18.7) If this is done, the fillet can be retained and the difficulty with surface (Y) overcome. In addition to scraping all the markings that are indicated, it is advisable to extend the strokes slightly beyond the spotted area into the fillet.

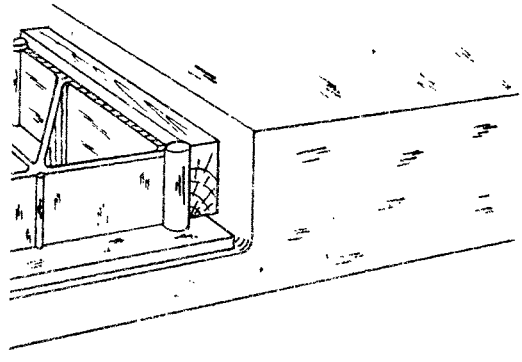


Fig 18.7 To provide a positive stop for the SURFACE PLATE short of the fillet, a straight flat board is used.

Sec. 18.8
Corners

Most machine members are designed with either a groove or fillet. Occasionally, however, a machine is found that has neither grooves nor fillets. Instead the adjacent surfaces are characterized by a design such as shown in Fig. 18.8c and Fig. 18.8d.

This form creates a special problem for the scraping operator who is reconditioning the surfaces. For a variety of reasons the stock advice to "Cut a groove" is not always feasible. One instance when the design cannot be altered

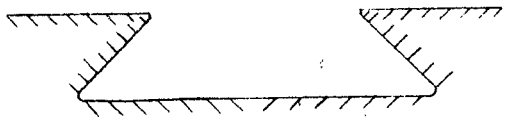


Fig. 18.8(a) Dovetails machined with a fillet.

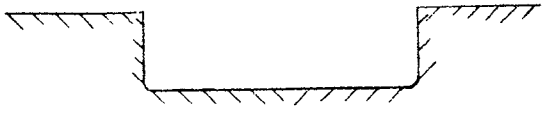


Fig. 18.8(b) Square edge machined with a fillet.

Fig. 18.8(c) Dovetails machined with a corner.

Fig. 18.8(d) Square edge machined with a corner.

is when slides and ways are pressure lubricated. In such cases the effect of a clearance groove would be to drain off the oil too rapidly.

To handle such a problem appropriately calls for two requisites. First, to apply marking compound, the operator must have a spotting tool that has over-all accuracy. Thus for spotting dovetails, an ANGLE STRAIGHT EDGE with a knife-edge is essential. For spotting a square corner construction a SURFACE PLATE or a standard STRAIGHT EDGE is needed.

Second, for efficient scraping the blade of the scraper tool must be altered to cope with the new condition. When a dovetail is to be scraped it is necessary to grind the scraper blade so that it tapers longitudinally being thinnest at the cutting edge. Such a blade will reach effectively into the bottom of the dovetail. (Refer to Fig. 18.11) Except for grinding the taper on the blade, there is no other variation from the conventional sharpening technique. The honing is performed in a strictly orthodox manner, as explained previously. After the tool has been given a keen edge, it is applied to the dovetail surfaces in the usual way.

For shaving metal from a square edge or corner it is preferable to employ two cutting blades. One is prepared as described above, namely with a taper, but the second blade is sharpened in a manner differing from the standard method. The principal modification is that the side of the scraper blade must be ground square with the cutting edge of the blade, as

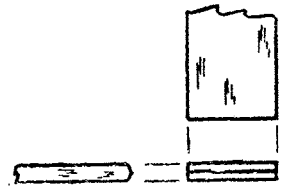


Fig. 18.9 Showing form of cutting edge after honing and grinding edge of blade 90° to cutting edge. (Corners are not rounded.)

represented in Fig. 18.9. The cutting edge is then honed in the customary fashion.

To scrape the inside corner of a square edge effectively, the tapered blade is applied in a direction square with or angled obliquely towards the vertical side. The blade ground square is stroked in a direction parallel to the side, as shown in Fig. 18.10. If chatter marks are to be avoided, the two blades must be alternated.

By observing these few precautions, corners of both dovetails and square edge construction can be successfully scraped without cutting a groove.

Sec. 18.9
Fillets and Corners as Manufacturing Expedients

To the scraper who has to wrestle with the problem presented by the fillets shown in Fig. 18.8a and Fig. 18.8b and the corners illustrated in Fig. 18.8c and Fig. 18.8d, it is somewhat mystifying why they are used at all. One reasonable assumption is that these designs are adopted by machinery builders in order to reduce production costs. By

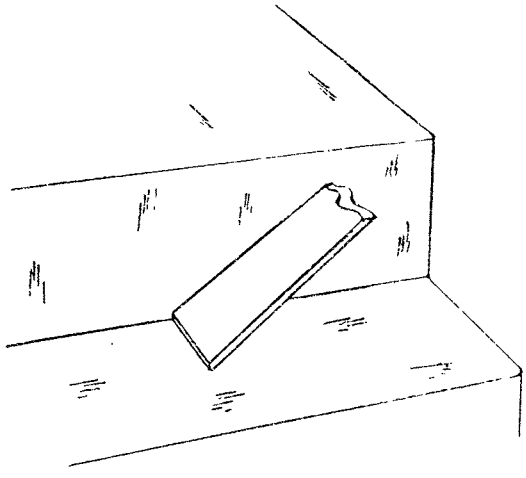


Fig. 18.10 Application of specially ground blade to inside corner of a square edge construction.

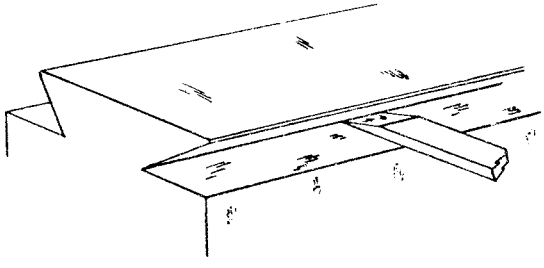


Fig. 18.11 Using a tapered blade on a corner of a dovetail construction.

eliminating the groove, one fewer operation is performed at the factory. Since there is no sacrifice of accuracy or adequacy of bearing surface in such designs, it is quite logical from a builder's point of view to use them. These surfaces can be produced at the factory, with high precision machinery generating extremely flat planes. Hand scraping is needed only to develop a close grained surface finish. This can be accomplished by the removal of very little metal, possibly a few thousandths of an inch.

The further fact that mass production factory techniques are widely followed, makes the employment of expensive, precision built spotting templates entirely feasible. Consequently, when treating machine members similar to those represented in Fig. 18.8a and Fig. 18.8b, the templates referred to are constructed to spot the full width of the bearing surfaces, stopping just short of touching the fillet. The machine member engaging these bearing surfaces is also designed to clear the fillet by a safe margin.

When working into corners, as represented by Fig. 18.8c and Fig. 18.8d, precision templates which will spot accurately into the full depth of a dovetail or against a square edge are again used.

It is the nearly perfect "finish machined" operation which makes practical designs such as these. Surfaces can be "finish machined" so flat and true on today's master machine tools that any scraping resorted to is not to obtain a fit but merely to provide a closer grained surface finish than can be obtained by the cutting tool. Sometimes in lieu of scraping, an abrasive block is simply rubbed along the bearing ways to remove the fuzz on a cast iron bearing surface. The slides and ways may be further finished by frosting or flaking if desired.

Sec. 18.10
Clearance of Mateing Members

Machine tools are designed so that the sliding members can traverse the stationary members without hindrance. At the time they are manufactured, they are provided with a clearance between non-bearing parts which, though small, is nonetheless adequate. Placed in use, deterioration sets in and the clear space narrows. Reconditioning, involving the scraping of the bearing surfaces, reduces the margin of safety still more, and not infrequently, it is exceeded. Unless this point is checked, it is not unusual for the members when returned to use to begin to rub together where they should not. If this condition prevails alignments are thrown out and the accuracy of the machine suffers.

Sec. 18.11
The Light Test

There is one practical test whereby clearance can be proved adequate, namely, the Light Test. This is a simple procedure that calls for placing the mateing members together with gibs adjusted to sliding pressure. A bright light located at one end of the members should be visible to the operator sighting between the

members from the opposite end. It should be seen clearly from all angles as the sliding member is moved to different positions. If this condition is lacking, the protruding portion of the casting needs to be filed away until there is sufficient clearance.

Sec. 18.12
Oil Grooves

Oil Grooves are channels, machined, ground or chiseled into the bearing surfaces of slides and ways. Their function is to provide a reservoir for oil or grease so that by maintaining a properly lubricated condition the service life of both ground and scraped surfaces will be lengthened.

The size of the oil groove, its form and its length, are not matters that concern the scraper except when it proves to be inadequate and must be enlarged. This is sometimes necessary when extra lubrication is required.

The oil grooves that are cut into the bearing surfaces of machine members may be formed in straight lines, curves etc. These grooves are not laid out with decoration in mind but are simply functional. Their sole purpose is to provide sufficient lubrication for the entire surface. If the surface is vertically positioned, the hole for the grease fitting or oil cup is drilled into the casting close to the top. The oil groove leads off from that point. Bearings positioned in the horizontal plane usually require several cups at spaced intervals.

Oil grooves may be put in before or after the scraping is completed. The important consideration is that the burrs and adjacent area which is raised by the blows (see NOTE) must be smoothed. If groove enlargement precedes the scraping, then the ensuing operations performed on the work surface will effectively eliminate all traces of the raised surface. On the other hand, should the oil grooves be chiseled into the work surface, or existing grooves be enlarged after the scraping is finished, then a spotting tool must again be rubbed on the work surface. This will indicate all raised areas and burrs. Do not depend on the unaided eye or the sense of touch alone to determine this.

NOTE:
In chiseling an oil groove the impact of the hammer blow slightly raises the metal surface forming a ridge. The raised area may extend on both sides of the groove for 1/8" or more, depending on the force applied. The bulge thus formed should not be confused with the burrs which form on the very edge of the groove. Formation of this ridge is a natural effect of concussion. Since hand chiseling is the least satisfactory method of cutting grooves, some operators prefer to use a small hand grinder when it is necessary either to cut a groove or enlarge an existing one.

Chapter 19

HINTS ON ROUTINE

After the fundamentals of scraping have been mastered, the operator who aspires to be a specialist must practice the art more intensively. This chapter aims to fill in a number of important points which though miscellaneous in character are conducive to proficiency.

Sec. 19.1
Starting a job

Before any scraping is attempted on a finish-machined work piece, the scraper should always measure it to make certain that a sufficient thickness of metal is available to enable him to accomplish his OBJECTIVES. These requirements usually include a condition of flatness, adequate surface bearing quality, correct dimensions and proper alignment of the work piece.

As a first step, the bearing surfaces should be roughly checked to determine if the relationship of the surfaces is correct so as to permit the necessary alignment to be performed. Unless this is done, there may be a considerable sacrifice of time and effort and even loss of material. For instance, it may be discovered too late that a partially scraped work piece cannot be fitted onto another part because excessive machining left insufficient metal to accomplish the OBJECTIVES by scraping.

On the other hand, it is a dubious advantage to have a thickness of metal in excess of actual needs. If an examination of a machined surface reveals a surplus it should not be hand scraped as this would be inefficient. It is preferable to employ a time saving alternative, namely, the power scraper. Possibly it may even be expedient to return the casting to the machine shop for a planing or milling operation if that would be more economical.

Sec. 19.2
Taking Over a Partially Completed Job

Sometimes an operator is assigned to replace another mechanic on a job. Because poor scraping can be so easily camouflaged, most scrapers dislike to take over unless they know that the preceding operator has a reputation as a conscientious workman. Even then they may be reluctant primarily because the second man will be held accountable for the entire assignment.

When a scraper assumes responsibility for a partially completed piece of work, it is advisable in any case to examine closely the results previously accomplished. One good procedure is to spot, at the very least, the last surface that was scrape-finished to determine its flatness and surface bearing quality. From this an inkling can be gained as to the care with which the former operator worked.

It is also worth-while to conduct alignment tests on those members of the machine declared completed by the retiring operator. This information should be recorded. All alignments of so-called completed parts must be within the allowed tolerances, and surface bearing conditions must be satisfactory, before the scraper may safely complete the unfinished work. These points are amplified in Chapter 23.

Sec. 19.3
Removing Excess Metal

The removal of a large surplus thickness from a bearing surface should always be done preparatory to hand scraping. This is only common sense. In studying ways and means to save labor, the relative merits of several alternative

methods, surface grinding, power scraping, milling or planing should be compared. Employing any one of these methods would effectively reduce the excess amount of metal to a thickness suitable for hand scraping, say 2 or 3 thousandths of an inch.

If scraping is to be the finishing operation, then the work piece should not be surface ground because grinding produces a very slick surface or skin that resists the penetrating action of the cutting edge. A considerable pressure is necessary to cut through a ground surface, and if ruptured forcibly, the tool marks formed will very likely lack the smooth finish required for a first class job. Furthermore, for the sake of appearance, it is essential to remove all traces of the grinding. Otherwise, the dissimilarity of two types of finish on the same surface will be incongruous and displeasing.

Machine grinding simply exaggerates the difficulty of the scraper's work, and the time element is increased not reduced. A high grade milling or planing operation is preferable to surface grinding in every case where scraping is to follow.

When a considerable quantity of metal must be removed, but not enough to justify machining, the employment of a power scraper, if one is available, is the practical solution. Consult Sec. 4.7.

Sec. 19.4
Lighting for the Job

To perform an expert scraping job all of the numerous minute surface irregularities must be seen before they can be removed. Thus good lighting becomes a prerequisite in this work. The preferred illumination for general scraping is daylight but the glare from direct sunlight is objectionable. When the natural light is insufficient, as it is in some shops, an artificial source is required to provide good working conditions.

Ceiling mounted fluorescent lighting, provided it is adequate, is the best choice. Sometimes this can be supplemented with a small, adjustable bench or floor lamp which is useful for concentrating a beam on a particular part of the work surface. In any event, shadows on the work surface are to be avoided because it is the variation in color of the marking medium that the operator uses to judge his scraping operation. Anything that tends to impair or obscure acuity of vision will induce eye strain and be a direct cause of inferior workmanship.

Lighting requirements for pin pointing are necessarily somewhat more stringent and they are discussed in Sec. 21.7.

Sec. 19.5
Selecting the Proper Spotting Tool for the Job

The preferred choice of a spotting tool is the SURFACE PLATE, provided it is large enough to cover the work surface completely. Unless the SURFACE PLATE has the requisite dimensions, plus the additional inch or two that the tool is moved while spotting, it is advisable to spot alternately with a STRAIGHT EDGE.

With long narrow surfaces such as flat ways, V's or inverted V's, the standard STRAIGHT EDGE is obviously the only practicable tool. For dovetails, and some V-ways an ANGLE STRAIGHT EDGE is compulsory because of the limitations of space.

Small templates (right angle, obtuse angle and dovetail types) are frequently employed for spotting purposes. These tools, though, are primarily intended for indicating angles, not to show the bearing quality. Ordinarily, they are not constructed large enough to indicate flatness over long surfaces. They must, therefore, be supplemented with other standard spotting tools.

Sec. 19.6
Alternation of the Spotting Tools

Many admonitions to vary the application of the spotting tools will be given in subsequent chapters. The reader is advised to alternate the SURFACE PLATE with the STRAIGHT EDGE and the STRAIGHT EDGE with some other kind of spotting tool, and so on. This should not be construed to mean that one must follow the other in an inflexible order, not at all. It simply means a wise selection and correct use of suitable gages to produce a good bearing surface in the shortest time. In other words, the

inadequacies of one type can be compensated in this way by the complementary qualifications of another.

When a spotting tool is slightly larger in both directions than the work surface, nothing is gained by substituting another in its place. However, ideal conditions do not always obtain and it is frequently necessary to employ two types interchangeably when neither by itself will completely cover the work. This practice is advisable because it reduces the possibility of forming a convex or concave surface when spotting with a tool of inadequate size.

Alternation of spotting tools is also recommended when scraping a bearing that must be kept at a definite angle to another surface. In such a case the intermittent application of a standard spotting tool with a small spotting template is urged. Incidentally, while the ordinary machinist's measuring instruments, such as the sine bar, vernier protractor etc., can and often will be used to check the angle in question, in many cases, a more appropriate tool will actually shorten the time element and produce superior work. This explains why the construction of small spotting templates having precise angles is so strongly urged for many scraping operations.

Sec. 19.7
The IDEAL POSITION for Spotting a Work Surface

Even when a work surface is located in the most suitable position i.e. the horizontal plane, it is difficult at best to spot it properly. To make matters worse, this choice position does not occur very frequently. On an average machine tool, the operator is fortunate if one out of ten surfaces to be scraped falls in this category. However, superior work can be performed if the two following conditions prevail.

1. The casting should be adjusted so that the spotting tool is fully supported by the bearing surface to be spotted. With flat bearings the work surface will, of course, be placed in a horizontal plane. If angular surfaces cannot be similarly accommodated, they should be tilted sufficiently so that the groove supports the weight. Thus only a light force is needed to press the spotting tool against the bearing to be spotted.
2. There should be ample room in which to manipulate the spotting tool.

Any abridgment of the qualifications noted above impairs the opportunity to spot a surface properly. Such design factors as dovetails, V-ways, inverted V-ways and square edges, all contribute to prevent the operator from attaining the ideal scraping position. Limitations of space and variations from a horizontal plane also militate against efficiency. In short, the absence of either of these two conditions is one of the several factors tending towards the formation of a convex surface which, as the experienced scraper well knows, is an ever-present hazard.

When the ideal spotting position exists or if adjustments can be arranged to bring it about, the formation of a convex surface is less likely to occur. For this reason the tool room should be equipped with a turn table such as is shown in Fig. 4.2. Small machine members when placed on this device can be tilted as required and even inclined surfaces may be adjusted to the horizontal.

Sec. 19.8
Position for Dovetail Members

The ideal position for scraping or spotting any dovetail surface is horizontal. This is easily achieved if the member can be mounted on a turn-table, such as shown in Fig. 4.2, and adjusted back and forth as needed. As an alternative, the component can be shifted around by hand, although it is pertinent to point out right here that the machine part cannot always be easily tilted from one plane to another. Usually the casting is so heavy, large or awkward to support that once it is fixed firmly in a reasonably convenient position, it is not moved until the dovetail is completed.

Under these unfavorable conditions the most accommodating arrangement is secured when the member is canted, so that the dovetail is situated about as shown in Fig. 18.4. This degree of tilt is simply a compromise that provides

maximum visibility and greatest freedom of movement for the scraping stroke consistent with convenient access to the work surface for the ANGLE STRAIGHT EDGE.

Sec. 19.9
Variations in Bearing Quality on Machine Members

Are all machine members scraped to the same density of surface bearing?

No, some discrimination should be exercised. In the process of producing a surface bearing on various types of machine members, consideration must be given to the function of the member, the frequency of cycling, its speed of traverse, the required precision of movement etc. These factors determine the number of bearing spots to be scraped into different types of sliding and fixed bearing surfaces. Quite properly the number should vary between surfaces, and the scraper will formulate his own OBJECTIVES accordingly.

The operator will evince good judgment by supplying to each type of surface the required bearing quality and will demonstrate efficiency by not providing more than is warranted under the circumstances. Surfaces having sliding contact require from 10 to 20 bearing spots per square inch. On the other hand, a surface which is connected to another member by bolting, and therefore not having a sliding movement, is adequately treated with a quality of 4 - 5 bearing spots per square inch.

Incidentally, when producing precision tools such as a SURFACE PLATE or STRAIGHT EDGE, a superior quality of 30 - 35 bearing spots per square inch is demanded. Even finer scraping is practiced on a few types of precision instruments. Spotting tools, templates, gages etc., vary from 10 to 30 bearing spots per square inch.

We have noted that the bearing quality supplied to one surface will vary from another having a dissimilar function. In this connection, it is sometimes advantageous to give a different quality of bearing to adjacent portions of the same surface. No rule of thumb has been formulated to govern this matter but the following classification may be informative.

1. The ways of stationary machine members are scraped uniformly overall, as a general rule.
2. With sliding machine members the answer is not so simple. In many cases, the short, sliding members that do not overlap the member they bear on can be deliberately dished in the central area to utilize an end surface contact. Lathe carriages typify this procedure. Another practice resorted to is to produce a heavier bearing at the ends of the sliding member i.e. a compound bearing.

These practices have as their purpose the equalization of wear when conditions are such that the ends deteriorate faster than the center area. This is frequently necessary in order to keep the machine tool in good operating condition for a longer period between overhauls.

Sec. 19.10
Compound Bearing Surface

A surface possessing an overall flatness, but with some parts of the total area provided with a greater or lesser number of bearing spots per square inch than other parts, is said to have a compound bearing. In other words, it is a surface divided into areas with varying degrees of bearing quality. This type of bearing may be applied to both flat and angular bearing surfaces on both stationary and sliding members.

It deserves to be emphasized that a compound bearing is not the result of accident but is deliberately created. Sometimes the surfaces of machine members are treated this way in order to equalize wear as between the ends and the middle area. The former are given a heavier bearing so that they will wear more slowly than the intermediate part which is given a lighter bearing. This is necessary because the extremities are subject to accelerated abrasion and consequently deteriorate faster than the center zone. To equalize the rate of wear over the entire surface as a whole, and to delay the formation of convexity, it is standard practice to develop a compound bearing.

When we speak of areas with varying numbers of bearing spots per square

inch, we do not mean that they are separated by sharp and distinct boundaries. Rather the lightest bearing is found in the middle, and a progressively better or heavier bearing is developed towards the ends. We begin to produce this physical condition only after the entire surface has first been scraped flat. Then the final bearing quality is worked in.

Skill in producing a compound bearing surface comes only with much practice but while experience is being gained a correct technique will help immeasurably.

To scrape a compound bearing surface successfully, proceed as follows:

After a condition of flatness and uniform bearing quality has been imparted to the work piece, the surface is altered to attain the compound bearing. To do this the surface is again spotted, and all the high spots indicated by the colored markings are shaved off. This must be done with discrimination. In the middle area selected for the lighter bearing, more pressure is applied to the scraping blade. The effect of this is to lower these high spots below the level of those at the ends. Consequently, the irregularities that are more heavily scraped do not reappear again for several spotting cycles. On the other hand, having been scraped more lightly, those nearer the ends will reappear at the very next spotting, or certainly after the succeeding one, together with additional high spots. In other words, the density of bearing at the ends increases progressively, while in the middle area, due to the method of scraping, it remains relatively unchanged.

There is no set rule whereby the operator can determine whether a surface should be given a compound bearing. It is necessary to analyze each case individually. Speaking generally, a compound bearing can be applied under the following circumstances:

1. To Slides:
   It is permissible when a sliding member has complete bearing contact throughout its full length of travel. In other words, the bearing surfaces of the sliding member must be shorter than the ways of the stationary member, and remain in full bearing contact throughout the end to end traverse.

   Example: The lower carriage surfaces i.e. slides of a lathe maintain full contact with the ways of the bed at all times.
2. To ways:
   When a stationary member is shorter than the sliding member, a compound bearing can be applied to the ways if they remain in full bearing contact with the slides throughout the end to end traverse.

   Example: The upper saddle surfaces i.e. ways, of a milling machine, have full bearing with the table slides in all positions.

Sec. 19.11
Compound Bearing for Sliding Members

Sometimes the slides of a moving part can effectively use a better bearing at the ends than in the central area. This will retard the premature onset of rocking caused by a more rapid wear at these points. When the sliding surface moves back and forth across the stationary surface, the extremities are constantly attacked by dirt, chips and grit. (Wipers effectively reduce this abrasion but do not eliminate it entirely) The mid-area, protected by its relatively remote position, deteriorates at a correspondingly slower rate. With normal use, this inequality of wear causes the surface to assume a convex curvature i.e. higher in the middle because of less wear. When the surface becomes sufficiently convex, the member "gives" or "rocks" under the pressure of a powered cut. The effect is quickly reflected in the lowered quality of work output. As this declines it indicates that the accuracy of the machine is impaired. Unless the tool is rescraped, its condition becomes progressively worse.

In attempting to secure a uniform rate of abrasion between the middle and the ends of a member, and thus prolong its useful life, either one of two courses may be adopted, namely:

1. Scrape the ends to a very dense bearing to exclude the dirt and grit. At the same time scrape the central portion giving it an average bearing. This treatment equalizes the rate of

wear between the different locations. It is known as a compound bearing surface.

2. Some operators think that prevention of "rock" is so important they deliberately hollow out, the central portion of the surface and develop an end bearing contact. This plan usually eliminates all danger of "rock", although now all of the wear will be concentrated on a smaller area. A lathe carriage with four pads bearing on the bed ways is a good example of this procedure.

Sec. 19.12
Touching Up

One particularly useful method of improving the bearing surfaces of machine members and making them more uniform is known as "touching up." Essentially it is a process of (a) removing the isolated high spots and (b) breaking up groupings of bearing spots.

The detection of these high spots, which is a necessary first step, is made possible by a brief use of the machine tool under simulated working conditions, such as when the members are slid back and forth a few times during an alignment test. This practice is often resorted to because the normal application of standard hand spotting tools will not always indicate the minute variations in height with sufficient definition to be readily apparent.

To prepare for this operation the bearing surfaces of the machine members are coated with a thin film of marking compound which acts as a lubricant as well as a medium. Next the sliding member is moved back and forth several times on the stationary member. This amount of movement is customary during the routine of an alignment test. Fortunately, even such a transient use of two mateing members will color a high spot so that it is readily distinguishable. Fundamentally, this is a spotting operation with the sliding member serving as a template while in the course of normal movement.

After locating the irregularities, the scraping blade should be applied lightly. The several isolated bearing points above the scrape-finished plane are shaved down and any clusters of bearing spots grouped densely are subdivided to produce a surface condition of maximum uniformity.

Sec. 19.13
Final Alignment Check With Oil

The final alignment check is made when the operator is satisfied that he has done his best in producing good surface bearing quality and accurate alignment of all members. To prepare for the operation, the machine tool is completely assembled in full operating order, and as each piece is attached, the bearing surfaces are coated with a film of light oil. This is essential because all of the marking compound, which in preliminary checks served as a cushion between the surfaces, has been wiped away. Without some kind of lubricant, the sliding surfaces would undoubtedly score when moved during the alignment tests. Furthermore, since oil will normally be used between the bearing surfaces, the machine should be tested for alignment under actual operating conditions. The oil applied should be the kind recommended by the manufacturer of the machine. This is particularly advisable with those moving metallic surfaces which must maintain an accurate height in relation to others. The type of oil, heavy or light, will have an appreciable effect on maintaining this height because of the thickness of the oil film.

Sec. 19.14
Final Alignment Check with Grease

Not infrequently, a machine tool is designed for grease instead of oil lubrication. In these cases it is preferable to make the final alignment checks with the same type of grease that is ultimately to be used in it during routine operations in factory or shop.

While it may be more convenient to perform these tests using oil rather than grease to lubricate the surfaces, convenience is not the criterion. Instead, the design of the machine should decide the nature of the lubricant employed for the final checks.

For example, when flat bearing surfaces are lubricated with a light oil, a machine may pass every alignment test O.K. But when the flat bearings are

pumped full of grease, preparatory to regular operation, a recheck shows the alignment is off by a wide margin.

Two factors are responsible for this phenomena. In the first place, a light oil may have been used during the alignment checking although the machine was designed to operate with grease lubrication. The difference in the film thickness may, therefore, be considerable. Secondly, the quantity of grease introduced to the system may be unequal on opposite bearings. This affects the alignment of the members by throwing them out by 1 to 5 thousandths of an inch. Since a terrific pressure is exerted by the hydraulic action of the grease gun, it is only common sense to be conservative when greasing the bearing ways. In a word, caution is imperative when performing this operation.

Grease lubrication on a machine introduces a problem that is not encountered in oil lubrication. While oil will flow freely from the high spots and spread uniformly, even when not under pressure, grease on the other hand, responds differently. Grease tends to remain inert and stationary and actually resists the application of pressure applied to it. When greasing the knee of a milling machine, for example, the bearing surfaces are forced away from the column ways by the pressure of the grease gun. Therefore, after greasing, it is advisable always to move the member so treated up and down a few times to distribute the lubricant uniformly over the entire bearing surface. If too much was used it will take considerable time and repeated movement of the parts before these members will return to their original alignment.

Sec. 19.15
Securing Alignments by Shimming

Before concluding this chapter it might be profitable to broach a new subject and discuss an aspect of alignment work which is rather frequently encountered. One practice that is sometimes expedient to employ is the insertion of shims when aligning two members having fixed bearing contact. The shims referred to consist of thin pieces of metal or paper laid betwen two surfaces to separate them by a calculated distance. By placing a strip underneath a member that is bolted against another it is possible to raise one end or side.

Though expediency is served in this way, it is not considered good workmanship to so effect an alignment which could be achieved by scraping. The principal objection is that when material is inserted between two castings there is an ever-present hazard that the pressure applied by bolting will induce a warp in one or both members. If a machine is torn down, however, and shims are discovered betwen the parts, they should be saved and replaced as found when the machine is reassembled. Otherwise, resort must be made to scraping to correct the error.

Chapter 20

FROSTING TECHNIQUES

The scraper should always be alert to methods which will enhance the appearance of his work. First and foremost among these are preventive measures to guard against accidental damage. This can best be done by observing all of the rules given in other chapters regarding scraping techniques, handling of tools and parts, and removal of destructive scraping burrs. The present chapter will deal mainly with procedures for decorating bearing surfaces and practical ways of removing minor surface defects.

Sec. 20.1
Determining Proper Treatment for Surface Flaws

The surface defects tha' are common to all machines, and especially to those with several years of service, are as follows:

1. New scratches. If these are found they should be turned under utilizing the method explained in Sec. 20.2 Camouflaging Scratches.
2. Old scratches. Sometimes these are so deep they cannot be removed during the scraping process. However, if the surface in question is to be decorated, they can be made less noticeable by blending them into the pattern of flaking or frosting marks.
3. Blemishes. Blemishes are small hollows that are too deeply worn into the surface to scrape out. These areas can be camouflaged with hand scraper tool marks while the surface is being scraped, if the subsequent application of a decorative pattern is not contemplated.
4. Dent burrs. These should also be scraped away before any decorative pattern is applied. The burrs spoken of here are not caused by the scraping process itself, but rather are humps raised when tools or other metallic objects are carelessly dropped on the bearing surfaces. At this time there should not remain even a trace of scraping burrs.
5. Blow holes. This subject is discussed in Sec. 20.3.

Sec. 20.2
Camouflaging Scratches

Although every operator does his best to avoid scratching the work surface, this mishap sometimes occurs. One common agent is the accidental lodging of grit particles between the work surface and the spotting tool. Regardless of the cause, when this happens the vital question is "How can I camouflage it?"

Fortunately, something can and should be done to disguise a blemish that impairs the appearance of the surface. This is not to say that there is any method, short of scraping below the scratch, that will make the surface as good as new. A careful, painstaking search can discover all attempts to cover up and hide a flaw. Nonetheless, the results of camouflaging are well worth the small effort.

An analysis of a newly abraded scratch shows that it is a channel or furrow bordered by ejected material called a burr. Due to the tenacity of metal, the burr formed by the scratch is seldom completely severed from connection with the parent surface. This fact alone makes possible the restoration of most surfaces, at least in part.

When a scratch is to be covered up, the following procedure works effectively. With the scraping tool held in the usual scraping position, the cutting edge is placed on the surface at the end of the scratch farthest from the operator. (See Fig. 20.1) Heavy pressure is applied as the blade is drawn slowly towards the body. The blade in this one motion, quite effectively pushes most of the raised material lying on either side back into

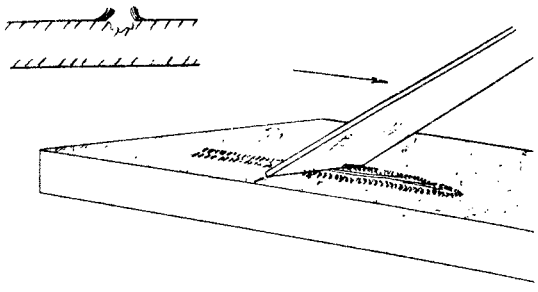


Fig. 20.1 Using heavy downward pressure and slow drawing movement of blade towards operator to force burr back into furrow.

the furrow. (Complete restoration is impossible) Experience demonstrates that there is no subsequent disintegration of this pressed-in material into particles to cause new scratches.

After the furrow is partially refilled, it is finished off with a series of light scraping strokes, directed from various angles, towards and across the scratch, blending it with the adjacent surface. The appearance of a surface having even a very unsightly scratch can be considerably improved if this method is applied with care.

Sec. 20.3
Blowholes and Their Treatment

A blowhole is defined as a cavity in a metal part formed by an air or gas bubble at the time the metal is cast. Blowholes are frequently encountered on scraping jobs and the operator should know the proper treatment for such contingencies. Sometimes new holes are discovered following a machining operation. Then again old ones are found to need attention, as when the plug already in them becomes loosened and must be renewed.

A blowhole located in the sliding member is an especially serious flaw and must be sealed off. If neglected, the core sand usually found inside will work loose, fall on the bearing surface of the way underneath and deeply score both it and the sliding member. Another reason for attending promptly to blowholes is for the sake of appearance. Even the small vents are unsightly and detract from the excellence of a scraping job.

Any number of materials may be successfully used as fillings. The selection depends on the size and construction of the member. Where the casting is sufficiently massive to stand localized heating without danger of warping, arc welding, brazeing, or silver soldering are suitable processes for sealing the cavity.

On small castings which might be adversely affected by excessive heat, molten lead which has a low melting point is often employed. To prepare the blowhole for filling with this metal, the perimeter or edge is cut back until it is free of all pit marks. Then the lip of the hole is undercut with a hand grinder or chisel so that when the metal is poured in, hardens, and contracts, it cannot fall out. This works well on large holes.

On the smaller holes, and those which cannot be undercut satisfactorily, it is advisable to use lead bismuth alloy. The notable property of this eutectic alloy is expansion while cooling, thereby providing a very secure and tight seal. It melts at a comparatively low temperature (approximately 240°F.) and it can be poured at about 300°F. After the filling is made the excess metal is scraped away.

Sec. 20.4
Frosting

One definition of frosting is the application of a decorative effect, resembling frost, to the conspicuous bearing surfaces of machines. (It is also called flowering.) Frosting consists of an ornamental pattern of marks covering prominently exposed areas of the bearing surface. It is produced by shallow cutting with a frosting tool.

The chief reason for the practice is to improve the appearance of a surface. A supplementary reason for frosting is to facilitate the lubrication of extremely smooth scraped metal surfaces subject to rapid or frequent traverses by other surfaces equally smooth. Here the purpose of the frosting is to roughen the surfaces slightly to provide oil holding pockets for adequate lubrication of the flat bearings.

Many manufacturers do not apply frostings to their machines believing that careful pin point hand scraping, while developing the requisite bearing quality, will produce a sufficiently attractive finish.

In frosting terminology "mark" refers to the cut made on the surface being

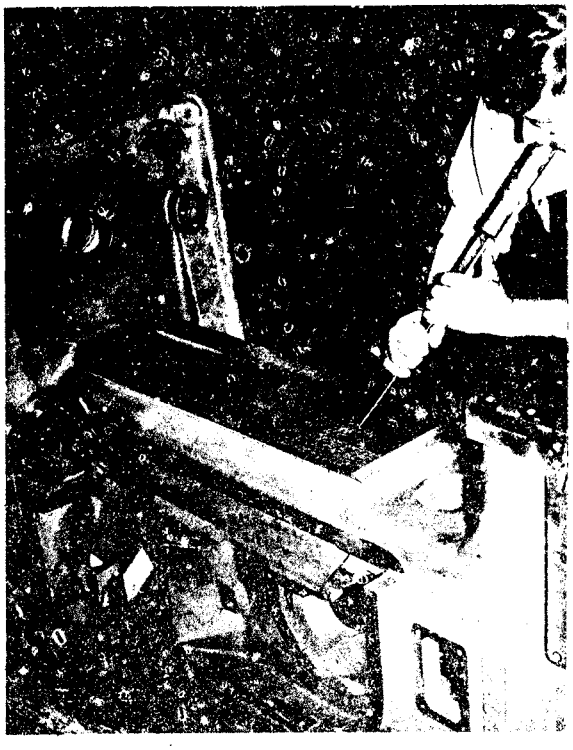


PLATE 14. Frosting (flowering) in process on the column face of horizontal milling machine. (Courtesy - Kearney & Trecker Corp., Milwaukee, Wisc.)

decorated. The tool is held by the operator in a suitable way and this is the "method" of handling the tool. The manner that the tool is struck, pulled or manipulated by the hand is designated "tactics." The shape of the frost marks formed is termed their "design." The arrangement of the marks on the surface of the work is called the "pattern." These definitions are amplified in later paragraphs.

Sec. 20.5
Talent and Dexterity

The possession of considerable artistic talent, in addition to a high degree of manual skill on the part of the operator, is requisite for success in this work. Since the personal touch is so much a part of frosting, and with the mechanic consistently favoring one or another mark or pattern, the appearance of the decorated surface often serves to identify his work. Every mechanic who undertakes to become proficient at frosting will experiment with the many possible designs. Since mastery in their application is acquired only by long practice, it is urged that advantage be taken of every opportunity to acquire proficiency.

Sec. 20.6
The Frosting Tool

The tool used in applying frost marks is the same familiar hand scraper employed for producing flat surfaces. To qualify for this new use the cutting edge must be ground and honed in a different manner and as a result the shape of the blade varies. This in turn affects the contour of the mark produced.

Sec. 20.7
Grinding the Blade

There are a number of ways to grind the cutting edge of the frosting tool. Variations in the method affect the form of the cutting edge, radial, straight etc. As stated before, these influence the design of the frosting mark. We will discuss one commonly used method.

The frosting tool is prepared for use by off-hand grinding the cutting edge of the blade with a pronounced arc. This operation is performed by holding one hand near the top of the handle to serve as a fixed pivot. The other hand is placed fairly close to the cutting edge. Then keeping the wide flat side of the blade parallel with the floor, the cutting edge is applied to the rotating wheel. Grinding is accomplished by moving the blade from left to right, that is, from side to side across the operator's body.

The hand holding the end of the handle acts as a stationary pivot, while the advanced hand swings the tool in an arc. In this way a curve having a considerable radius is ground on the cutting edge. Incidentally, if the cutting edge is pitted, grinding should be continued until smooth.

Sec. 20.8
Honing the Blade

Next the blade is honed. One method

of honing, which produces a cutting edge capable of making the arrow head or crescent mark and modifications, will be described.

This operation is similar to the grinding method just discussed. In brief, the tool is gripped by the left hand fairly close to the cutting edge, keeping the narrow, thin side of the blade facing towards the operator's body. The end of the handle is grasped with the right hand and held in a vertical position over the bench stone. The right hand will serve as an immovable pivot point. By using the left hand to supply the movement and pressure for the honing stroke, the blade is honed, to and fro. Fig. 20.2 illustrates the shape of the properly formed cutting edge after honing.

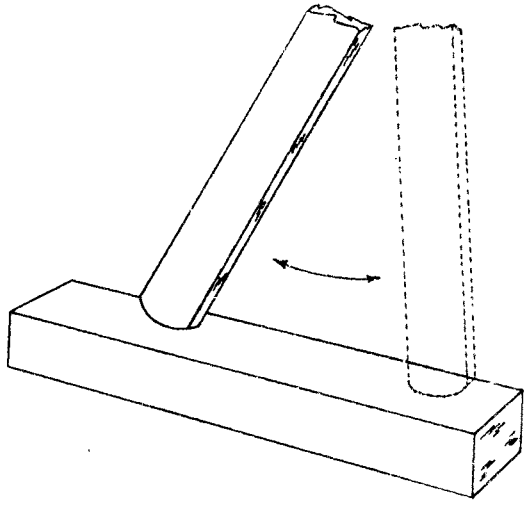


Fig. 20.2 Showing method of honing a blade capable of producing crescent frostings. With narrow side of blade facing toward operator, the tool is swung back and forth, pivoting from end of handle to develop a radial edge.

Recapitulation

During the grinding operation the frosting tool is so grasped that the flat or wide side of the blade is parallel to the floor. The end of the handle is held stationary and pivots the cutting edge of the tool from left to right in an arc against the grinding wheel.

In the honing procedure, the blade is supported vertically with the narrow side always facing towards the operator. The cutting edge is stroked to and fro along the length of the bench stone. A pendulum motion is imparted, with the end of the tool handle fixed and pivoting from this end while the cutting edge swings in an arc in contact with the bench oil stone.

Sec. 20.9
Holding the Frosting Tool while Frosting

A common method of holding the frosting tool to produce artistically patterned frost marks, is as follows:

1. Rest the handle against the left shoulder, so that the tool is held upright approximately between 70° and 85° with the work.
2. Apply downward pressure to the tool, at about the midpoint, with the left hand.
3. Rap the flat of the blade sharply with either the open palm or the closed fist of the right hand. Direct the blow close to the cutting edge. The harder the tool is hit the farther the edge will skid. Since this affects the formation of the mark, hitting should be uniform. With light pressure the surface is only bruised; heavier pressure makes a deeper cut.
4. Draw the frosting tool closer to the body with each blow struck against the blade in preparation for the next.

Sec. 20.10
The Frosting Stance

When frosting a work surface the operation should be started at the far side. To get into the proper position, the operator must lean over and, if necessary, stretch. The tool is placed at the very edge and hit smartly. This is repeated many times meanwhile guiding the blade straight across the surface or diagonally. But in either case, the blade is drawn closer to the body with each blow struck, finishing at the near side of the surface. In order to obtain uniformity of frost marks the operator should assume the most natural position possible. Whether sitting or standing, his posture should be relaxed so that the element of physical strain will not contribute excessively to the tendency to vary the marks.

When frosting is continued for any extended period, the need for controlling the physical inclination to relax and change position becomes even more urgent. Changes in body position affect the force

of the blow, its direction and depth, all of which alter the mark. Since frost marks must be similar in design to be attractive, they should be inspected individually and continuously as they are formed; and if non-conforming, steps should be taken to correct the cause of the distortion before forming the next mark. That is to say, a running inspection is made in step with the necessary modifications of stance, hitting tactics etc. so that there is no interruption of the frosting routine. Incidentally, the need for uniformity is the reason that only one operator should be assigned to frost a given piece of work. Two men cannot produce identical designs.

Sec. 20.11
Hitting Tactics

There are several techniques by which spacing between frost marks is accomplished. For example, the operator may hit the tool continuously without deliberately moving the blade and produce a chain-like formation of marks from one end of the work to the other. Then skipping a space equal to the width of one frost mark another row of marks is worked onto the surface, again from the far to the near side. After the surface is decorated by rows of frost marks, with alternate unmarked strips, the work is given a 90° turn and the process completed in the undecorated portions. In addition to relieving monotony in the pattern, this practice will cause the frostings to be more clearly seen when viewed from different angles.

Another tactic is to start at the far side of the surface and hit the tool towards the near side. After each blow the tool is pulled slightly closer to the body before hitting again. This will space each mark from the next one. Row after row is made separated by strips of unmarked surface. After turning the work 90° the blank strips are frosted.

A third tactic that makes an attractive pattern is to stagger the marks. Starting at the far end of the work piece the blade is struck once. From where it stops the blade is shifted to either left or right the width of a frost mark and hit again. Shifting back and forth in this fashion makes a double row of marks spaced at intervals. When the surface has been worked over, it can be turned 90° and the unmarked gaps filled in. After the work is completed, a checker-board pattern is revealed.

In the three examples of tactics just given, the operator hits the blade directly toward himself meanwhile drawing it in the same direction. By hitting obliquely, that is at a tangent to the direction the blade is pulled, the mark produced may be modified in appearance.

Sec. 20.12
Design of Frosting Marks

The frost marks that are formed on the bearing surfaces with the frosting tool, range from simple designs to others quite elaborate. Arrowheads, crescents, butterflys, quarter-moons and rectangular chain effects are some of the possibilities. This is not to say, however, that all kinds are jumbled haphazardly together. Rather, the operator selects one design and applys it uniformly to the surface in question.

Uniformity in the applied marks is very desirable but it is difficult to maintain for long periods due principally to muscular fatigue. Therefore, the operator should avoid undertaking too large a surface until considerable skill and experience has been acquired.

Sec. 20.13
Consistent Reproduction of Frost Marks

Many factors enter into the consistent reproduction of a particular mark. The operator soon discovers that a frosting tool of a certain keeness, held at a fixed cutting angle, tilted slightly off center, when struck by the hand with a blow of a definite force, directed in a particular direction, will produce a mark that best suits his taste. With experience it is possible to closely approximate the conditions which will duplicate it. No one else will be able to imitate his mark exactly and it will be as personal as handwriting. It will be a kind of trademark of the scraping specialist. Machinery bearing this mark would be identifiable throughout the world.

Sec. 20.14
Factors Modifying Design

The factors influencing the design produced on the frosted surface are summarized as follows:

1. The sharpness of the tool, ranging from fairly sharp to very keen.
2. The manner of holding the frosting tool.
3. The blade's angle of inclination to the work surface.
4. The manner the cutting edge contacts the surface, either at the apex of the well curved blade or canted to the left or right.
5. The degree of pressure applied to the cutting edge.
6. The force of the blow against the blade.
7. The direction of the blow, either straight toward the operator's body or oblique.

Some of these points will now be amplified.

It is obvious that when one factor is emphasized more than another, it becomes a major influence in determining the design of the frosting mark and also modifications thereof. For example:

1. With the frosting tool honed to the shape suggested in Sec. 20.8, the design of the mark can be varied quite radically by changing the angle of the tool with respect to the work. To pose an imaginary case, let us examine the effect of a variation of tilt from 85° maximum, to say 70°. If the blade is held at the extreme angle of 85°, it will produce a thin crescent mark that has widely separated points. See (a) in Fig. 20.3.

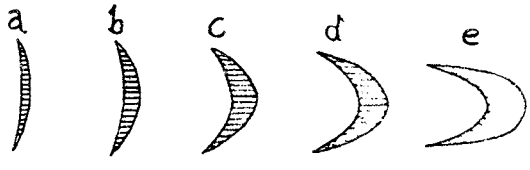


Fig. 20.3 Several patterns of crescent frostings produced by the same cutting edge by varying the angle blade inclines toward work surface (enlarged).

As the blade's angle of attack is lowered, other factors remaining the same, the distance across the points of the crescent mark decreases progressively, as seen at (b), (c) and (d) respectively. At the minimum angle for efficient work, about 70°, the points of the crescent mark are closest, as shown in (e). It is plain, therefore, that even with slight changes in the angle of penetration, the frosting tool can produce assorted crescent designs. These finally merge into other forms which might be classified more descriptively as arrow-heads.

2. A fairly sharp blade will produce a mark of a certain width and depth. On the other hand, a keener edge will create a narrower and deeper mark because it is more penetrating. By honing the blade to a selected degree of sharpness, from fairly sharp to very keen, and maintaining it that way, a uniform frosting mark is easily achieved.
3. Marks may be made wider by hitting the blade of the tool with greater force. Conversely, the marks produced are narrower if the blows are less vigorous.
4. Continuous, rapid hitting, without consciously moving the blade, causes a chain of marks to form. Deliberately shifting the blade after each rap generates a completely different pattern.
5. Tilting the blade to the left, or right, so that some point off center rests on the work surface, gives the mark a new individuality.
6. Propelling the tool across the work surface by striking the blade towards the body, makes a mark of a certain kind. It is possible to vary it, provided other factors remain constant, by merely striking the blade obliquely to the left (or right).

Sec. 20.15
Avoiding a Mechanical Pattern

While the individual marks frosted on the work surface should be kept uniform, it is best to avoid applying them in a too regular or too monotonous fashion. Their position when altered slightly introduces variety and interest and thus transforms an otherwise purely mechanical appearance. One of the devices by which this is done is diversified spacing. Another method calls for rotating the

work piece.

Marks are usually frosted on the surface with 50% of them running in one direction and the other half of the marks formed after turning the work piece by 90°. If this procedure is adopted, the arrangement of marks creates a pleasing pattern. Should something more ornamental be required, the rows of marks can be frosted in three directions. Thus one third of the work surface is frosted with the marks laid in one direction. Then the work piece is turned 60° and another one third of the surface is treated. Again the work piece is rotated by 60° and the balance of the surface is dealt with.

To create another interesting pattern, the frostings can be applied in an irregular fashion. That is to say, about one third of the entire surface is frosted scatteringly with marks running in one direction. After turning the piece by 60° another third of the surface is similarly treated. Following another 60° turn the balance of the marks is applied.

Sec. 20.16
Special Method of Holding the Frosting tool

Certain types of bearing surfaces, such as dovetails, are difficult if not impossible to frost if the tool is held in the manner previously prescribed. This method, though satisfactory for horizontal surfaces, places body and hands in awkward positions with respect to the hard-to-get-at surfaces. To cope with this problem, experienced frosting operators hold their tool in a special way.

The tool is grasped about in the middle with the left hand. The tool handle should not point towards the body, nor rest against the shoulder, as in the method first described. Rather, the tool blade is held with the wide flat side in front of, and broadside to, the body. The cutting edge is to the left, in contact with the work surface, while the handle inclines obliquely upward to the right at about 45°. When the end of the handle is rapped smartly with the palm of the right hand the cutting edge skids under the impetus of the blow and a frost mark is formed.

With this method of frosting, the possible variation in design is not so extensive, ranging perhaps from (c) through (e) Fig. 20.3. This is due to the one point suspension and relatively inflexible attack angle of the blade. Nonetheless, this method produces good designs having adequate penetration. And even more important, surfaces which are angularly inclined, or in an otherwise awkward position, can be easily and competently frosted.

The grinding and honing of the blade is performed in the same manner as previously described. Consequently, there is no change in the shape of the cutting edge.

The appearance of the frosting mark produced by this method is also influenced by certain factors, such as keeness of the blade, force of the blow, pressure imposed on the cutting edge by the left hand etc., which were touched on before.

Either method of frosting is not too difficult to learn, and as experience is gained, any mark or design may be closely duplicated whenever the occasion demands.

(We have mentioned but two of several methods of producing frosting marks. Space will not permit a discussion of other and equally effective techniques of a similar character.)

Sec. 20.17
Preparing the Work Surface for Frosting.

Before applying the frosting tool, a thin film of bluing is often spread on the work surface. The advantage of this practice becomes quickly apparent as the cutting edge of the tool removes a portion of this bluing with each stroke. Against the overall blue background, the frost marks begin to stand out quite clearly as a sharply contrasting color as the bluing is shaved away, making it easy to observe the progress of the work. Slight errors in handling the tool, changes in the force of the blow and other non-uniform factors causing variations from mark to mark, can thus be more quickly detected and remedied. In short, the blue background helps to secure uniformity.

Sec. 20.18
Removing Scraping Marks before Frosting

Frosting marks are applied either directly over the scraper tool marks or after the latter are removed by lapping. As a general rule, where a distinctive

appearance is an important factor, a uniform background, minus scraping marks and with frosting marks closely spaced and shallowly cut, is preferable.

A simple method of lapping a work surface to obliterate scraping marks is as follows:

The first step is to coat the surface with a film of kerosene. Then a sheet of fine grit emery cloth is wrapped around a flat piece of metal of handy size. The surface is lapped striving to apportion the strokes uniformly. Unless deeply cut, the scraping marks are removed quickly without any appreciable deterioration in surface flatness.

Lapping is not always resorted to. Sometimes the desire for ornamentation is superseded by the necessity to improve lubrication on a surface receiving severe duty. Then the scraping marks are retained and the frost marks are overlaid. They may be cut more or less deeply depending on the class of service the machine is subjected to. The spacing between marks can also be varied. Either practice increases the oil reservoir capacity proportionately.

Sec. 20.19
Butterfly Frosting

Another unusual type of decoration that produces a quite attractive mark is butterfly frosting. The mark is different, not only in its design, but also unique in the method of production. Fig. 20.4 illustrates the frost mark which resembles a butterfly with wings outstretched, hence the name.

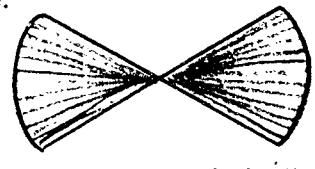


Fig. 20.4 Example of butter fly frosting mark.

To make this design, the common hand scraper is again used. However, contrary to the method previously discussed, it is ground square across. Then it is honed to a very keen edge, while held in a vertical position over the stone. No matter what method of honing is employed, the cutting edge should be made as square and flat as possible without curvature. The four corners are rounded slightly to avoid scratching the work.

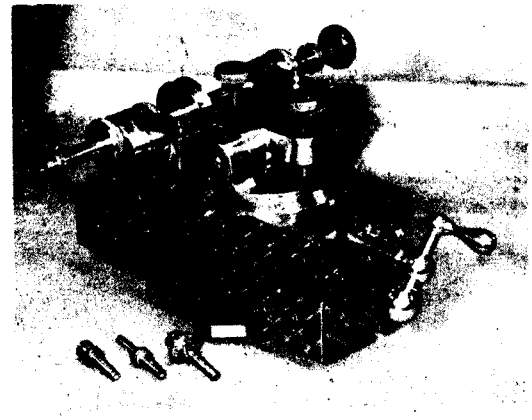


PLATE 15. Showing butterfly frosting on Universal 3-slide grinder attachment. Three grinding wheel collets are shown in foreground. (Courtesy - Elgin Tool Works, Chicago, Ill.)

At the start of the butterfly frosting stroke, the tool is placed on the work surface in front of the operator and so held that the narrow side of the shank faces the operator. The tool is tilted to the right approximately 30° from vertical. The left hand presses forcibly down on the tool from a position near the cutting edge. The right hand holds the end of the handle and swings it around quickly with a circular motion, in a clockwise direction. A turn of about 60° is made. In spite of the pressure of the left hand, the design is not incised very deeply into the surface. Actually, the metal is just slightly grazed.

Uniformity of design depends upon keeping the cutting edge from skidding as the turn is made. To prevent this the left hand steadies the tool so that the pivot point will be in the center of the blade's cutting edge. It takes a conscious effort on the part of the operator to achieve and maintain this centralized pivot point. This axis cannot be allowed to move because if it does the design will be spoiled. Practice will enable the operator to twist the blade without slippage.

The positions occupied by the cutting edge of the tool at start and finish of the clockwise movement are represented diagrammatically in Fig. 20.5.

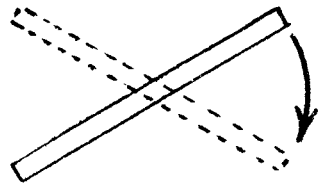


Fig. 20.5 Start and stop positions of cutting edge of frosting blade on work surface as required in producing butterfly frosting marks. Pivot point is at center of blade.

Sec. 20.20
Mechanical Frosting Methods

To expedite the job of decorating large areas of surface with frosting marks, mechanical devices, known to the trade as "spotters" or "frosters" have been developed. One type consists of a tool very similar to the ordinary hand scraper. Attached to the shank is a small wheel which engages a slotted steel guide track.

The spotter is held at an angle of about 30° and pushed across the work surface with the small wheel engaging the guide track. This guide induces a rocking motion causing the blade to cut crescent shaped spots as the tool is advanced. By adjusting a thumb screw on the tool, various shapes of frostings are obtained, thus making it possible to adopt the design most suitable for different types of work.

Using this apparatus, almost any unskilled workman can perform decorative marking at a speed several times faster than an expert can frost by hand. Frostings produced with the "spotter" are nearly as attractive as expertly produced hand frostings, and they are more uniform without being too mechanical in appearance. Of course, such frostings are easily distinguishable from hand frostings.

The principal drawback of the mechanical froster is that it cannot be used in confined quarters, such as dovetails. Here the limited spaces make hand frosting necessary. Usually in such a case, as much of the work piece as possible is mechanically frosted and then the dovetails and similar "hard-to-get-at" places are finished with hand frostings. This is entirely feasible because the mechanical "spotter" makes a mark of simple design that may be closely duplicated by skilled manual operators.

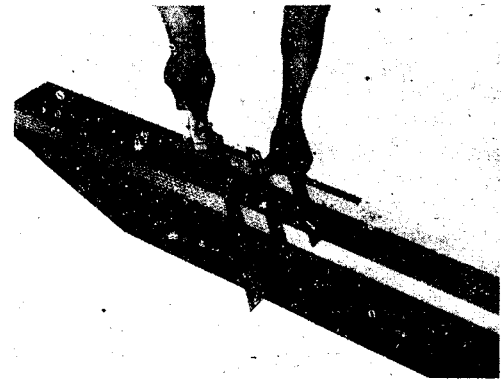


PLATE 16. The single hand spotter for light work. (Courtesy - Anderson Bros. Mfg. Co., Rockford, Ill.)

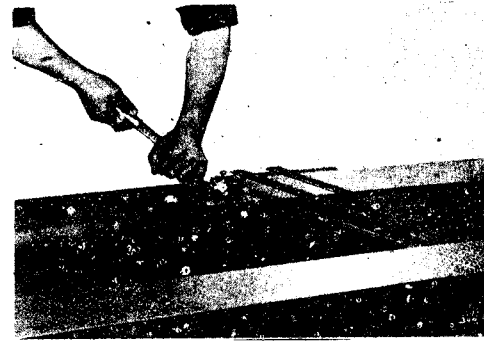


PLATE 17. The long spotter for heavier spotting. The guide is clamped rigidly to work piece. (Courtesy - Anderson Bros. Mfg. Co., Rockford, Ill.)

Sec. 20.21
Flaking

Flaking is the term denoting a decorative patchwork effect given to both bearing and non-bearing surfaces. (This terminology is also descriptive of the formation of oil pockets to aid lubrication on bearing surfaces requiring them.

There is very little similarity between flaking and frosting. The designs generated by each process are different, as well as the technique employed in producing them. These differences, notwithstanding, a certain laxness of language has developed among practitioners of the art, when referring to the two processes. Among some operators the expressions

are used interchangeably as though they were synonymous. Others erroneously confuse the techniques by giving the name of one to the other and vice versa. It is hoped that the attempt of this book to clarify the terms will be well received.

Sec. 20.22
Size, Shape and Pattern of Flaking Marks

When flaking for decorative effect the entire work surface is covered by marks cut very slightly into the surface. Generally speaking, flaking marks are formed as squares or rectangles. They may be either large or small and laid on in either a regular or irregular pattern. To make the regular pattern as pleasing as possible, the flaking marks can be applied in checkerboard fashion with 50% cut in one direction and the remainder incised at 90° to the first half. Not infrequently, the flaking marks are laid on in a staggered pattern to provide greater variety.

Sec. 20.23
Handling the Flaking Tool

In preparation for flaking, the blade of the tool is ground and honed as flat as possible especially when the marks to be formed are large. No curvature is given the cutting edge except for lightly rounding the corners to prevent scratching the surface.

Flaking marks for ornamental purposes are produced as follows:

The tool is held in a fashion similar to hand scraping, with the left hand below the middle and the right hand grasping the end of the handle. The tool inclines to the work at about a 30° angle. When the cutting edge is stroked across the work it is done lightly so as to only graze the surface. A reciprocating, to and fro, motion is imparted to the tool and this regulates the length of the flaking mark.

Following the initial forward stroke, the cutting edge is shifted sidewards, say to the left, without lifting the tool, and additional overlapping strokes are delivered. The number of shifts determines the width of the mark produced. For a large flaking design of say 1" square, the lengthof the cut is extended 1". Then depending upon the dimension of the tool blade the cutting edge is shifted sidewards a number of times until a mark having a width of 1"is attained. Fewer shifts and a shorter forward stroke are required when the flaking mark is smaller, as for example a 1/2" square.

As an aid to flaking a surface for decorative effect, bluing may be spread on the work surface. The marks will show distinctly against the blue background making uniform results somewhat easier to achieve.

Sec. 20.24
Flaking Oil Pockets

If the purpose of flaking is strictly utilitarian, that is, designed to provide a number of oil reservoirs, the marks are cut deeper and no definite pattern is attempted. Usually the marks are flaked half in one direction and the other half at 90° to the first group. However, instead of completely covering the surface, a mere one or two marks every few inches is considered sufficient for most jobs, even fewer in some cases.

To produce flaking marks suitable for oil pockets, grasp the tool with the left hand and hold it across the body. The blade should incline at an angle of 30° to 45° with the work. By striking the end of the handle a smart blow with the palm of the right hand, either a square or rectangular mark is formed depending on the force employed.

The work surface should be "burr filed" after flaking to remove the burrs that inevitably are raised by this process.

Sec. 20.25
Circular Flaking

A circular flaking mark is sometimes given to a surface by charging a piece of soft material, such as wood or cork, with an abrasive substance. This block of material is then fastened in a drill chuck in either a drill press or a hand electric drill. By pressing the rapidly revolving abrasive material against the work surface, circular flaking marks are produced. Multiple patterns are possible. This type of flaking mark, however, is never found on a piece of high grade machinery. Essentially, it distinguishes

the handicraft of the home workshop enthusiast.

Sec. 20.26
High Quality Scraping Marks

Work surfaces that are carefully pin point hand scraped are, in most instances, attractive enough without adding refinements. This effect is achieved not only by the painstaking removal of metal but by a methodical change in the direction of the scraping strokes on alternate cycles to prevent the formation of chatter marks, as discussed previously in Sec. 6.9. Thus not only is the bearing quality improved but the appearance is enhanced simultaneously as the surface is given a regular pattern of scraper tool marks. From a practical stand-point, such a surface is truer than if some form of decorative marking were applied.

Chapter 21

AUTOMATIC GENERATION of GAGES

Automatic generation of gages and tools is possible only through resort to the Principle of the Symmetrical Distribution of Errors. This expression is applied to any method in precision work which results in dividing, or splitting, errors until they finally disappear. The basic principle of dividing errors is one of the oldest known in mechanics, yet is still frequently employed today. For example, it is utilized in the production of SURFACE PLATES, STRAIGHT EDGES, ANGLE PLATES, SCRAPED PARALLELS, CUBES, etc.

By the application of this principle, a high degree of precision in scraping operations is possible. In theory, splitting the error may continue until it reaches the vanishing point, and the ultimate in accuracy is achieved. In practice, however, the degree of dexterity in handling the scraping tool and the ability to make precise tests constitute limiting factors.

In the following pages are discussed not only the methods of accomplishing automatic generation of precision gages but also other matters closely related to their production. Included in this category is the special process of scraping called pin pointing. Also described are the methods usually employed in spotting, matters pertinent to selecting a proper scraper blade, and the steps in preparing suitable illumination for pin pointing work.

Sec. 21.1
Automatic Generation of Surface Plates

When there is a need to make a precision gage, say a SURFACE PLATE, two methods are feasible. One is the commonplace process of spotting on a MASTER SURFACE PLATE. Unless this tool is available to check the progress of the work, it is impossible to determine the character of the surface being scraped. Lack of such a tool, as a standard for comparison, necessitates the adoption of the other method.

By utilizing the well known theorem "Two things equal to a third thing are equal to each other" it is possible for the skilled mechanic to prepare three metal castings and scrape them to SURFACE PLATE quality without benefit of Master Gages. Indeed when the process is completed, each casting will have been scraped to Master Quality.

If the castings are to be scraped flat and true, it is essential that the dimensions of each surface be the same or nearly so. For the purpose of this demonstration, we will assume that the three surfaces are 16" square. If built in the customary pattern, with thick top and sturdy supporting ribs, the castings will be fairly heavy, about 70 lbs. each. This massive design is necessary to provide rigidity to the casting and strength needed for supporting the heavy weights of work pieces laid on top.

Such a casting is hard to handle, yet care in manipulating it is mandatory. It is not superfluous to caution about bumping one casting against another. This may happen during the spotting process when separating the upper from the lower plate. Damage to the castings is frequent enough to make worthwhile a detailed explanation of the cause.

For example, as the surfaces of the three plates are scraped more and more flat, there is a tendency for any two of the plates to stick together, bonded by the marking medium. An unwary mechanic lifting the top plate by the handles will simultaneously raise the lower one as well. Although the connection breaks almost immediately, the upper plate freed suddenly may tilt, even though held by the operator, and strike the lower plate causing burrs. Any practical way of anchoring the bottom plate to the bench, so that it will not lift off with the upper one, solves the problem neatly.

There are two variations in the method

of automatically generating SURFACE PLATES and both techniques are widely used. Since there are important differences between them, each will be discussed separately.

Sec. 21.2
Method No. 1 (Known as the 2 over 1)

The actual process is commenced by first numbering one side of each plate with chalk or paint, #1, #2 and #3, respectively. It is assumed that all three castings have previously been rough machined, stabilized and finish machined to a reasonable degree of flatness. They should also have been rough scraped all over to remove the extremely rough spots.

In placing the plates in contact, their chalked sides are always positioned one above the other. Furthermore, when rubbing the upper plate back and forth, it should be held from the side that is chalked. The reason for this was discussed in Sec. 11.7.

OPERATION NO. 1

Application of marking medium is made to Plate #1, which serves as the "marker" in the first operation. Plate #2 is then placed on top. Care must be exercised when easing the plates together so that all edges line up.

Working from the chalked end, Plate #2 is pushed and pulled a distance of about one inch. While this is being done, every effort should be made to keep the sides from overlapping during the four to six movements. Then the plate is lifted directly off, inverted, and the markings are scraped. Cleaning the plate of all marking compound and metal scrapings is the next step. Finally, the burrs are removed and the plate is stroked with the bare hand to detect stray foreign particles.

Continuing operation No. 1, the marking compound on Plate #1 is reworked and a little more is added if necessary. Now Plate #3 is laid on Plate #1, with the chalked ends of each facing the same way i.e. adjacent. Careful placement assures that the edges of the upper plate coincide with the edges of the lower. Grasping the upper plate from the numbered end, it is pushed and pulled about one inch. Excessive overlapping of the sides during the half dozen movements can be avoided with careful handling.

When the marking medium is transferred the plate is lifted directly off. Plates should never be slid together, either when laying on or separating. This precaution becomes increasingly important as the surfaces are scraped smoother. Sliding the plates yields false readings and, as a consequence, the closer the surface approaches SURFACE PLATE bearing quality, proportionately more time is spent in fruitless work.

Concluding the operation, Plate #3 is placed face up on the bench. After scraping the markings, the plate is cleaned of marking compound and metal particles. Next a bench stone, or a burr file is applied to the surface to remove the burrs. Finally, the plate is wiped with the bare hand. At the same time Plate #1 is thoroughly cleaned of all compound and foreign matter.

OPERATION NO. 2

Selecting plate #2 as the "marker" for this operation, a film of marking compound is applied to it. Next Plate #1 is laid on the "marker" plate, observing all previously mentioned recommendations. After rubbing Plate #1, it is removed to scrape the marks. Cleaning the surface and removing the burrs therefrom, prepares it for subsequent operations.

If the "marker", Plate #2, requires more marking compound it should be added, otherwise reworking the surface film is sufficient to prepare it for the next spotting. Resuming, Plate #3 is laid on the "marker", rubbed carefully, and set back on the bench.

It is essential to have the bench as scrupulously clean as the work itself. The operator's clothing should not be contaminated either. The obvious danger from minute specks of foreign matter adhering to the work surface and causing false markings is only one unfortunate result of negligence. Another and still more distressing effect is deterioration of the plate by scoring. It is possible for even a small piece of grit lodged between the rubbing plates to cut a groove deep enough to undo hours of painstaking labor. Such a happening would be an even more serious matter in the final stages of

spotting when the film of marking medium is necessarily thinned to a minimum and hence is insufficient to lubricate the surfaces and cushion a stray particle. The operator should remember that direct metal to metal contact is usually the case in the final spotting operations. And of all combinations compounding friction, two unlubricated, cast iron surfaces seem to be the most susceptible to injury. Dry cast iron surfaces score very easily and dirty surroundings simply aggravate conditions.

Continuing the routine we scrape the markings showing on Plate #3. After cleaning the plate the burrs are removed. At the same time all spotting compound is cleaned from the "marker."

OPERATION NO. 3

The only plate not yet used as a "marker" is Plate #3. Since it, too, should take its turn in the sequence, a film of marking medium is applied. One after the other, Plates #1 and #2 are laid on the "marker", rubbed and removed. Plates #1 and #2 are scraped where the markings indicate high spots. Both are then cleaned, their surfaces are smoothed of burrs, and all grit is brushed off with the bare hand. Finally, the spotting paste is wiped off the "marker" and one cycle is completed.

Automatic generation, utilizing the principle of the Symmetrical Distribution of Errors, which involves the mere repetition of the cycle, will produce the fine degree of flatness desired in SURFACE PLATES. That is to say, routine cycling will eventually produce the desired results.

Despite its seemingly mechanical character, the novice should not underestimate the difficulty of the work and the severe demands it imposes on the operator. The difficulties increase in a geometric ratio the nearer each surface approaches a true plane. Progressively, the distinction between the shades of coloration becomes more and more fine, hence good lighting and keen vision are indispensable. Adept handling of the scraper tool to shave off the thinnest particles of metal is requisite. Concentration must be both intense and enduring, even though cycling is many times more tedious and long drawn out than on ordinary jobs. In other words, the highest calibre of workmanship must be employed to bring about the formation of a true plane.

As explained elsewhere the usual oil base marking mediums, including Red Lead, are not appropriate for the final spotting cycles of surfaces requiring a very fine finish. Particularly for finishing precision spotting tools, they are far too crude. The most suitable marking medium for high quality work is alcohol which subject is discussed in some detail in a later paragraph.

The spotting and scraping procedure is continued until a surface quality of 30 - 35 bearing spots per square inch is obtained. (Refer to Sec. 8.2)

Sec. 21.3
Method No. 2 (Known as the 1 over 1)

There is a second method of automatically generating flat SURFACE PLATES. It is accomplished by the following procedure:

Three castings are needed. For purposes of illustration, cast iron flats 16" square are used. Their preliminary preparation is a duplicate of the treatment outlined for the previously described METHOD NO. 1. In brief, the cast iron flats are finish-machined, heat treated, rough scraped, and cleaned.

The plates are numbered #1, #2, and #3, respectively. The numerals are chalked on one end of each. When placed in contact the numbered ends should be one above the other. The operator must manipulate the casting by grasping the numbered end. This, of course, has been pointed out repeatedly, but any confusion on this score causes so much trouble that we bring it up once more.

Marking compound is spread on Plate #1. Then this plate is spotted on Plate #2. All precautions urged for the first method are equally appropriate for this system as well. After spotting, Plate #1 is cleaned thoroughly. Meanwhile the markings showing on Plate #2 are scraped.

Following this all burrs are removed from Plate #2 and its surface is cleaned. Marking compound is then applied to Plate #2 which is spotted carefully on

Plate #3. Plate #2 is now cleaned of all marking compound. Next all markings appearing on the surface of Plate #3 are scraped. Continuing the routine, Plate #3 is cleaned of all contaminations, after which it is coated with a film of marking medium. Plate #3 is rubbed on Plate #1. Finally, Plate #1 is scraped and thoroughly cleaned.

This series of operations constitutes one cycle and the repetition of the cycle will bring each work surface closer and closer to perfection. The advantage of this process is in the opportunity it offers to reduce labor and increase speed. By applying a slightly improved plate for each spotting it is possible to accelerate the work. The faster rotation of the cast iron flats reveals more quickly the condition of the surfaces, thereby indicating the areas needing priority attention.

Although greater speed is possible, more head work is also needed in order to take full advantage of the possibilities inherent in this system. To derive the maximum benefit from the potentialities of Method No. 2, it is advisable after each spotting to sketch on paper the location and size of the areas marked with compound. By using Markings Charts for comparison and analysis, the danger of scraping false markings, and thereby worsening the surface, is considerably reduced.

In any variant of the three plate method of generating flatness, mere mechanical repetition of the cycling will eventually produce the desired result. But since none of the plates are perfect to start with, the high areas of the marker plate may sometimes spot the low areas of the second plate. In other words, a convexity on one may nest into a concavity of the other. If the low area is marked with compound, the natural tendency is to scrape it, thereby unnecessarily lowering it below the possible finishing plane i.e. that point where, if no mistakes were made, the surface could be perfected.

This may be excusable during the first few cyclings because no one can tell exactly what the character of the surfaces is like. However, it is during these first cycles that much unnecessary work can be saved if the Markings Charts are used. It is at this time that the Charts provide the maximum information. By portraying an accurate picture of surface conditions, the scraping of low areas that may be marked can thereby be largely avoided.

In the final analysis it is the operator's ability to sense the true character of the work surface and his own skill as a scraper which will determine the choice of methods he will use.

Sec. 21.4
Usefulness of the Markings Chart in Generating Three SURFACE PLATES from Cast Iron Flats.

The Markings Chart (Sec. 11.8) is a positive aid in generating three SURFACE PLATES from three castings. Perhaps the biggest help it furnishes is in assisting memory, as explained previously. Another benefit it provides is in avoiding mistakes by making it easier to identify the false marks which appear during the early scraping cycles. This phenomena is sometimes noticed when producing SURFACE PLATES or other tools by Automatic Generation. (This subject was touched on in Sec. 11.3 and can be somewhat amplified here.) Briefly, the situation faced when the process is started is more comprehensible if it is remembered that the markings seen on the face of one cast iron flat were formed, not by a trustworthy gage, but by another unfinished cast iron flat. Thus, while these markings may truly indicate high spots, on the other hand, the marks in question may simply denote a convex or high area on the cast iron flat serving as a marker i.e. spotting tool. In short, the markings may be ambiguous.

The Chart is helpful in analyzing the surfaces of the cast iron flats, and in following the progress of the work. Since the marks themselves are only temporary, being scraped and cleaned off preparatory to the next spotting cycle, some sort of record is clearly advantageous. Because the Chart does provide a handy summary of the work accomplished and eliminates the almost impossible task of remembering whole series of markings on three separate castings, it is a logical practice in the scraping art.

Knowing the character of the surface on each cast iron flat, the high areas may be worked down more energetically. In many cases some of the markings may

be disregarded altogether because reference to the Charts shows that they are false or at best only half true. This may seem to contradict the general practice of scraping all the markings that show. However, the reason for this departure from standard procedure is that some of the markings on the work surfaces may not be high spots at all. If a little headwork is mixed with routine scraping far less metal needs be removed in bringing the work to a flat and true plane.

The demonstrably false markings, as well as those of indeterminate status, which are encountered as the job is begun, will be automatically rectified and become wholly reliable as the work progresses. The Markings Chart is intended to assist the operator in becoming aware of their true nature from the very start, thus speeding the work.

Sec. 21.5
Automatic Generation of Straight Edges

To produce STRAIGHT EDGES by automatic generation, the same methods of spotting, scraping, and cycling that were previously explained in Sec. 21.2 and Sec. 21.3 are again adopted. Reviewing this material will be helpful. A STRAIGHT EDGE may be originated by either the "1 over 1" or "2 over 1" method.

Because of their elongated form these tools are easily subject to distortion due to rough handling. Therefore, special care must be exercised to avoid bumping these tools and inducing a warp. Every safeguard suggested in Sec. 21.1 Generating A Surface Plate, is equally applicable in the present instance. A few other particularly helpful pointers are added herewith.

The production of a STRAIGHT EDGE begins with the preparation of three castings of equal size. This is essential if accurate tools are to be made. The castings are rough machined, stabilized then finish machined. Now that they are ready for spotting and scraping, a special problem arises. Unlike the broad based SURFACE PLATE, the STRAIGHT EDGE is not self supporting and stable. It is necessary to provide a fixture or cradle to hold the tool in an upside down position so that it may be scraped.

The fixture must be made strong enough to support, without excessive rocking or lateral movement, the weight of the second casting during the spotting operation. In addition, it should have sufficient rigidity to resist, without wobbling, the pressure of the scraping cut. Such a fixture can be of simple wooden construction proportioned to fit the size of the STRAIGHT EDGE being produced.

Consideration should also be given to easy insertion and removal of the casting to facilitate the work. The design also must allow for clamping devices to hold the STRAIGHT EDGE in the cradle without slippage. The design of the clamp must be carefully considered to avoid distorting the casting when fastening it down.

Three hints especially pertinent to generating STRAIGHT EDGES are enumerated below.

1. Number one end of each casting with chalk, #1, #2, and #3, respectively. When spotting, always grasp the castings at the chalked end. Place the numbered ends together.
2. Position the castings one on the other, in such a manner that the edges line up. Rub the top casting back and forth a few times, for a distance of about one inch.
3. Since STRAIGHT EDGES ordinarily are of quite narrow width, no side pressure whatsoever should be applied while spotting because this will lead to inaccurate markings.

The production of STRAIGHT EDGES demands the same painstaking care and intense concentration that is required in the making of SURFACE PLATES and other precision gages. The spotting and scraping procedure is continued until a surface quality of 30 - 35 bearing spots per square inch is obtained. (See Sec. 8.2)

Sec. 21.6
Automatic Generation of Parallels

Hand scraping a PARALLEL, when only one of these tools is required, is an elementary operation. It consists of spotting and scraping one surface of the casting until flat. The casting is then inverted and the opposite surface is treated. Tests for parallelism must be conducted periodically with precision tools and gages.

Producing PARALLELS in sets of identical size is a more difficult operation which can be accomplished in either of two ways. The mechanical processes are by far the most common. This method of manufacturing a set of hardened and ground steel PARALLELS is a machine operation performed by a precision SURFACE Grinder, and hence is beyond the scope of this book.

The other method is by hand scraping, utilizing the principle of the Symmetrical Distribution of Error. This is a very tedious job because of the two essential OBJECTIVES which must be attained. They are given as follows:

1. The two scraped surfaces of the individual PARALLEL must be parallel.
2. The distance between surfaces or planes must be the same for all three PARALLELS produced.

To demonstrate an imaginary case, three castings of approximately equal dimensions of the type shown in Fig. 4.3a are procured and rough machined all over. They are aged and then finish machined on all surfaces. The machining of each piece should be as close to identical dimensions as possible, in order to reduce the amount of hand scraping.

The first scraping operation consists of scraping one side only of each casting to a SURFACE PLATE accuracy and bearing quality. The three pieces having been scrape-finished on one side, are numbered #1, #2 and #3, respectively. The numbers are chalked or painted on one end only, for a reason to be explained.

For the next operation, which is the first application of the principle of the Symmetrical Distribution of Error, only two castings are employed at a time. Pieces #1 and #2 are laid on a SURFACE PLATE with the scrape-finished faces underneath and with the unchalked ends facing the operator, as represented in Fig. 21.2. (Piece #3 is temporarily set aside.) Another SURFACE PLATE is brought to the work bench and a film of marking compound is applied to it. This SURFACE PLATE is placed on top of the two castings which are then spotted in the routine way. After the compound is transferred to the two work pieces they are scraped in accordance with the markings.

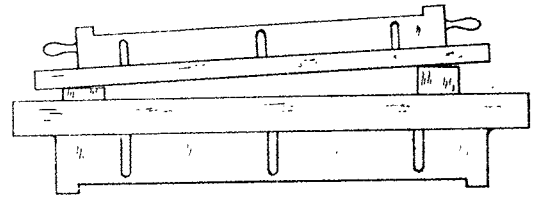


Fig. 21.1 Method of determining the thicker PARALLEL. Lay PARALLELS side by side on SURFACE PLATE. Spot with another SURFACE PLATE. The PARALLEL marked on inner edge is always the thicker of the two.

It is understood that even if both castings are of different heights, both will be marked, although under these conditions only a line contact will occur and the markings will show on only one end of each. The scraper must interpret the markings accurately. The marked area on the thicker of the two castings is then scraped. On the other hand, the marked portions on the thinner casting, after it has been identified, are not immediately scraped. This identification is not difficult to make as reference to Fig. 21.1 will show. As the castings become more nearly the same thickness, closer scrutiny will, of course, be needed to interpret the markings correctly.

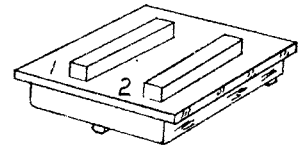


Fig. 21.2 Position of PARALLELS #1 and #2 at start of spotting. Unchalked ends face operator.

The two pieces #2 and #3 are now laid on the SURFACE PLATE in the order shown in Fig. 21.3. The spotting gage is

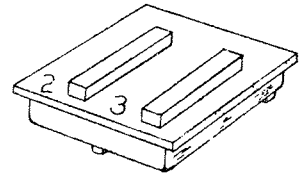


Fig. 21.3 PARALLELS #2 and #3 in position to be spotted. Unchalked ends face operator.

placed on top of them and rubbed. (NOTE: The unchalked ends face the operator

during the process of rubbing.) The markings on pieces #2 and #3 are analyzed and scraped, as with the previous set. Next pieces #1 and #3 are treated in a similar manner. (Fig. 21.4)

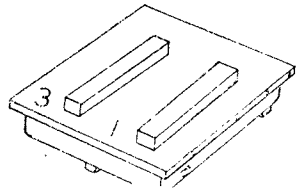


Fig. 21.4 To complete first step PARALLELS #1 and #3 are spotted. Unchalked ends face operator.

If this cycling process, which is the same as that used to generate SURFACE PLATES, were merely to be repeated, we could give each casting a flat surface without transverse taper. However, we would not be able to control any longitudinal taper which might develop. For this reason we must now begin to reverse the position of the chalked end of the castings, one at a time.

Thus the next operation finds the two pieces arranged on the SURFACE PLATE in the order shown in Fig. 21.5. Pieces #1 and #2 are used, but this time #1 is reversed, that is to say, turned end for end so that its chalked end faces the operator. This transposition is made deliberately to halve the error and represents the second application of the Principle of the Symmetrical Distribution of Error.

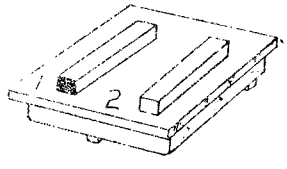


Fig. 21.5 Showing PARALLELS #1 and #2 on SURFACE PLATE ready for second step in generation. PARALLEL #1 is turned end for end so that chalked end faces operator.

The other SURFACE PLATE is applied in the customary way to perform the spotting. Afterward the markings are scraped away.

This procedure is carried out according to the actual schedule shown in Fig. 21.6

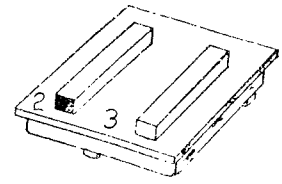


Fig. 21.6 PARALLELS #2 and #3 are positioned with #2 turned end for end so that chalked end faces operator.

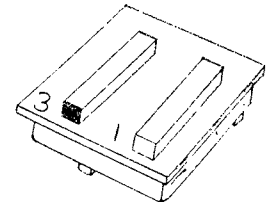


Fig. 21.7 PARALLELS #3 and #1 are positioned with #3 turned about so that chalked end faces operator.

and Fig. 21.7. Analysis of these drawings will disclose that each casting is turned end for end in regular sequence. The cycle of operations is repeated again and again until all three pieces are identical in all vital dimensions. It is possible to prove this condition by the following test, to wit:

1. Lay all three pieces on the SURFACE PLATE in any position, in any order and facing in any haphazard direction.
2. Place the second SURFACE PLATE on top of them.
3. After spotting, compare the transferred markings. If they are uniform on all surfaces, in respect to coloration, number and distribution, the three castings now may be properly classified as identical SCRAPED PARALLELS.

If a variation is apparent, resume the cycling. By continuing the scraping, using this method of rotating the pieces, the distance between surfaces may be carried to any degree of accuracy that is desired. Incidentally, during the concluding scraping cycles it will be advisable to employ a marking medium providing the thinnest film as this will facilitate obtaining the desired degree of precision and surface bearing quality. For this

purpose alcohol would, perhaps, be the best choice.

The surface quality given the PARALLELS should range from a minimum of 20 bearing spots per square inch for average cases, to a SURFACE PLATE quality of 30 - 35 bearing spots per square inch when tools of highest precision are wanted.

Sec. 21.7
Pin Pointing Precision Tools and Gages

Work requiring a very fine finish, such as a testing gage, is never brought to a high degree of perfection with the methods and materials employed for average scraping jobs. This type of scraping is characterized by the term "pin pointing". While pin pointing procedure is similar in many respects to the technique adopted for average "run of the shop" scraping, there are enough differences to justify a detailed outline of the process.

In reality, pin pointing is a bettering of a scrape-finished surface. That is to say, it is a continuation of finish scraping. The one begins where the other terminates. This is readily seen by considering the evolution of a work surface from rough to smooth. The normal routine, embodying spotting and scraping is repeated many times. A point is finally reached during the job when, no matter how lightly the marking medium is spread, the weight of the spotting tool exaggerates the extent of the high spots. Under the pressure of metal surfaces, even a thin film of marking medium often covers two or more adjacent high spots, as well as the contiguous low areas. Obviously, this distortion nullifies the usefulness of the marking medium from there on.

Bluing, red lead etc. serve very well for most scraping jobs, but when a super finish is ordered, they are a little too crude. Alcohol is the accepted medium for the exacting pin pointing process.

A typical procedure using alcohol as the medium will be described in the operations which follow:

1. Both the work surface and the MASTER SURFACE PLATE are thoroughly cleaned with a volatile solvent to remove all grease, marking compound, and foreign matter. A wiping cloth can be used to start but the job should be finished with the bare hand to be certain that the surfaces in question are free of all thread and lint.
2. Alcohol is applied to the work surface and spread around with the fingers and hand. This application of liquid quickly evaporates depositing a nearly imperceptible residue to dull the surface.
3. After placing the piece of work on the SURFACE PLATE, it is rubbed slowly back and forth a distance of about one inch, four to six times.
4. The work should be carefully removed, inverted and laid on the bench. You now observe a small number of highly polished marks on the otherwise dull surface. These denote the high spots which are to be scraped off or pin pointed.
5. To facilitate scraping, the work piece is situated in the best available light, such as provided by a desk or floor lamp positioned close by. The surroundings preferably should be in semi-darkness so that only one light source is reflecting from the work to the operator.
6. The polished marks which denote minute irregularities are scraped very lightly. Only enough metal is removed to take away the polish, but every spot that is visible must be dealt with. Attention to details becomes more important the closer the surface approaches perfection. The pin-pointing process shows better results if the cutting edge of the tool is kept very keen. Furthermore, to make a shallow cut the angle of the blade with respect to the surface should be the minimum possible.
7. After each scraping cycle, thorough cleaning of the surface of all metal scrapings is requisite.
8. All burrs are removed but without causing scratches. For this purpose the experienced operator will select either a smoothly worn burr file or an oil stone of fine grit, such as an Arkansas. Another suggestion is to rub a highly polished, hardened steel block over the surface to knock down the slight burrs raised by even very light pin pointing. (When nearing the end of the job, the burrs are so insignificant they may be disregarded.)

9. After removing the burrs and thoroughly cleaning the surface, it is advisable to explore it with the hand to detect foreign matter. This should always be done before again placing the work piece in contact with the spotting tool.
10. Meanwhile the SURFACE PLATE should be examined in a similar manner. Grit of sufficient size to cause damage is sometimes carried by air currents a surprisingly long distance from other parts of the shop and deposited on the tool. Visually it is non-apparent, but it is detectable with the bare hand.
11. Occasional cleaning of the SURFACE PLATE with a solvent is recommended to remove any foreign matter which may accumulate. This matter is too fine to scratch the tool's surface or the surface of the work. But being of a gummy nature, composed of metallic dust, a residue of alcohol, and the excretion of oil and perspiration from the hands, its cumulative effect is enough to cause false markings on the work.
12. In pin pointing the high spots it is better to start from the side nearest the operator and work in a direction towards the far side. This is advisable because the high points are indicated by small polished spots which are easily obscured or obliterated if accidentally touched with the hands or smudged by oily fingers.
13. The entire surface should be pin pointed before attempting to brush away the litter of fine metal particles scraped from the work. This debris serves during the pin pointing operation to outline the limits of the area already dealt with.
14. Needless to say, precision scraping a surface is a time consuming and tedious operation. It cannot be hurried. If the operator feels himself becoming tired and developing a mental condition of "It's good enough" he should suspend work for a while and resume later when refreshed.

Sec. 21.8
Illumination for Pin Pointing

All scraping operations need good illumination, but for the final pin pointing of a work surface requiring many bearing spots per square inch, the lighting demands are particularly exacting. This is understandable when considering that the high spots in many cases are no larger than 1/64" in diameter and scarcely visible, even under ideal conditions.

For pin pointing work, ceiling lights are undesirable because the rays tend to disperse at all angles, making it exceedingly difficult for the operator to see the burnished high spots. Illumination located directly overhead, or somewhat to the side, will cause gleams to shoot from many scraped facets (formed by scraping strokes) directly to the eye of the operator. These bright glints coming not alone from the burnished high spots but also from nearby portions of the surface make the detection of the burnished high spots just that much more difficult. Moreover, they cause unnecessary eye strain and slow up the work as the operator must determine whether the gleam comes from a high spot or from a facet developed by a previous scraping stroke.

Since all high spots must be removed it follows that all gleams must be investigated. In view of these circumstances, concentrating on a specific high spot among these many distractions becomes unusually perplexing.

The proper illumination for pin pointing is an adjustable desk lamp having sufficient beam intensity to reflect readily from the burnished high spots. If possible there should be only a single source of light. It should be placed close to the work surface facing the operator, not to one side. Preferably, the area surrounding the work piece should be kept in comparative darkness.

When pin pointing a precision tool, such as a SURFACE PLATE, where the highest accuracy is required, a piece of black cloth or paper, suspended in back of the work will deaden glare from extraneous sources. Its use also facilitates the detection of high spots.

Sec. 21.9
Choice of Blades for Pin Pointing
(Narrow vs. Standard Width Blades)

Pin pointing a SURFACE PLATE, or for that matter any piece of precision work, requires the elimination of all the

very small irregularities. This operation necessitates a somewhat different technique than average scraping in that the high spots when located are removed individually.

Superficially studied, it might seem the better practice to scrape the isolated high spots with a blade having a very narrow cutting edge, so as not to graze the adjacent area. Since the high spot is about 1/32" or less in diameter, a blade having a cutting edge of about 1/8" or 1/4" width would appear to be quite appropriate. Such a selection could be made, but the disadvantages of using a narrow blade for pin pointing far outweigh the benefits.

We will mention only a few of the objections to a narrow blade. In the first place, to hold such a narrow blade flat against the surface is very difficult, and if tilted inadvertently, a scratch will almost certainly occur. If the job demands a first class appearance, the entire surface must be re-worked to eradicate the blemish.

Then there is the difficulty of learning to hone a narrow width blade. Even if the knack is acquired after long practice, it is an impractical accomplishment because it would be useful only for the special purpose of pin pointing. Finally, the narrow width blade makes for slow progress in scraping. The operator, being unaccustomed to the blade, will be unable to handle it with his accustomed skill. Unfamiliarity with the tool combined with the pressing need for superior workmanship, creates an impressive psychological barrier to satisfactory results.

On the other hand, the advantages of using a standard width blade are genuinely substantial. Such a blade, honed by the usual hand method, develops a curved edge which is equally as capable of pin pointing as it is of rough scraping. Furthermore, being familiar with it, the operator will be able to produce more and better work with less bodily fatigue and eye strain.

The combination of (1) The normal slightly curved edge, with (2) The angle the tool is held with respect to the work surface, and (3) The applied pressure, determines what percentage of the cutting edge is presented to the high spots. Where the high spot is small, as on a nearly finished surface, only a slight force is exerted on the blade. This in turn decreases the effective width of the cutting edge. By this co-ordination of factors the correct cutting edge for all occasions is provided by the radial curvature automatically produced on the standard width blade.

Another advantage is that it can be tilted or rolled slightly without danger of scratching the surface. Not infrequently, in making a stroke, the operator by canting the tool, misses the high spot he intended to cut down. With a standard width blade, such a bungle does not mean a scratched work surface, as would be the case with a narrow blade.

Chapter 22

STANDARD TESTS

To attain the desired accuracy, proper fit, and adequate bearing quality, a scraper must employ continuously and conscientiously a variety of tests. These are designed to supply information as to the condition of the surfaces being treated. Tests have been devised to detect convexity, nonparallelism, and wind; also to reveal the closeness of fit of mateing members; and to indicate such essential characteristics as area contact, bearing quality, and surface finish. Since they are all tried and proved methods, the operator should have no hesitance in applying them. Familiarity with these tests will greatly simplify the operator's work.

Sec. 22.1
Tests for Convexity

Almost without exception, every reconditioning job on a sliding bearing involves the reduction of a convex surface to a true flat plane. Primarily, convexity is the result of wear, and the extent of this deterioration must be ascertained before any intelligent effort can be made to correct it. Various tests have been devised for this purpose and those most appropriate are conducted at frequent intervals as the surface is scraped flat.

In addition to testing for convexity caused by wear, these tests also guard against the accidental generation of this defect during the process of scraping. There seems to be a tendency among many operators to generate a convex condition by scraping more deeply when approaching the edges of a work piece. Thus we find a peculiar situation where, even in the process of reducing a convexity, there is an unconscious inclination towards the development of a new curvature. Because of this, it is necessary to maintain constant vigilance from start to finish of a job in order to produce a true flat plane.

Sec. 22.2
The X Test

One of the simplest methods of determining the convexity (or concavity) of a large bearing surface is the X test. It is performed best with a STRAIGHT EDGE and, if carefully executed, is a good indicator of surface conditions.

Before making the test the first step is to clean the work surface thoroughly. Then a very thin film of marking compound is spread on the STRAIGHT EDGE. The quantity to use depends on the condition of the work. A nicely finished surface naturally requires less than one that is quite rough.

Having spread the medium, the tool is laid diagonally from one corner of the work surface to the opposite corner. After spotting the work surface, the tool is removed. The spotted area is now inspected for uniformity as to coloration, number, and distribution of markings. Next the markings on that portion of the surface that will be spotted by the STRAIGHT EDGE when it is placed crisscross in the other direction, are carefully erased. This would be the area bounded by (a), (b), (c), and (d), as seen in Fig. 22.1. After reworking the compound, the

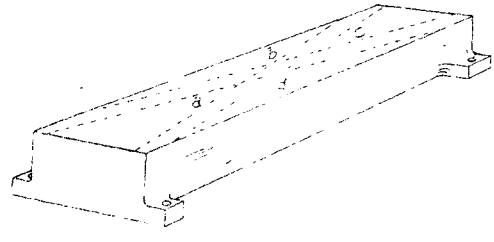


Fig. 22.1 Pattern of markings formed on a flat surface by a STRAIGHT EDGE when using the X test. Remove compound from area bounded by (a), (b), (c), and (d) before criss-crossing the tool on the second lay.

tool is laid diagonally so as to form the second leg of the X. The first leg is overlapped at that point where the compound was removed. The X pattern of markings thus transferred is studied and analyzed. If it is uniform overall on both legs, it may be fairly assumed that the surface is flat, provided care was exercised in manipulating the tool.

The X test is valuable to the operator because it reveals any minute deviation from flatness in the surface as a whole. In other words, one criss-cross spotting provides a sampling or average reading of the overall surface. As a test, therefore, it is superior to laying the tool straight across because this checks only a narrow area in but one direction and, moreover, represents but a small fraction of the entire surface. With the X test system, we have the advantage of bridging directly from the highest to the lowest point on the surface. By this method, it is possible to detect the presence of a deformation so minute as to be hardly noticeable by any other procedure.

The alert reader will note that the effectiveness of the test is limited by the length of the available STRAIGHT EDGE. Generally, this confines its application to members of short to medium size.

Fig. 22.2 shows the X test being applied to a casting having a recessed surface. In

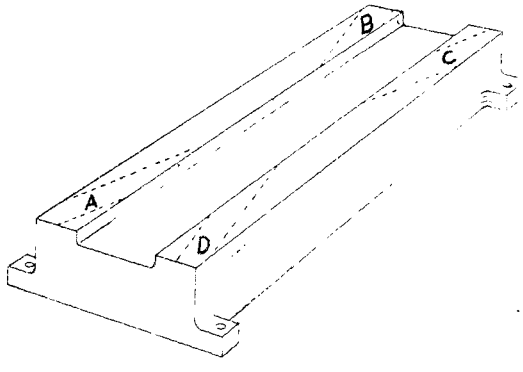


Fig. 22.2 Example of the X test on a surface having a recessed area. Flatness indicated if areas (A), (B), (C), and (D) are uniformly colored and markings evenly distributed.

a case such as this, the uniformity of the markings at the extremities of the surface would indicate absence of convexity.

If a SURFACE PLATE were used to span the surface it would reveal a convexity somewhat more easily. But this would be true only if the tool was large enough to cover the entire surface at one lay. A small SURFACE PLATE would be unsatisfactory because if slid along a surface much longer than itself, it will only follow the curvature and spot the contour accordingly. (Refer to Fig. 9.2) This tends to obscure the curvature as judged by the markings, and the accuracy of the analysis is impaired.

In addition to testing for curvature, the X Test is equally capable of detecting the presence of "wind", and on the shorter members, is frequently used for this purpose.

Sec. 22.3
Pivot Test (Spin Test)

Even when working under ideal conditions and exercising the greatest care, it is still possible to scrape a convex curvature into the work surface. Very long surfaces, especially, are inclined to develop this phenomena. Consequently, it is advisable to make periodic checks of the work surface so that any tendency towards a curvature may be detected at once. Another favored method by which this can be investigated is known as the Pivot Test.

This test may be performed with a STRAIGHT EDGE in either of two ways, viz:

1. Immediately after the work surface has been spotted. This practice is utilized when the surface might have roughness which may score the face of the gage. The resulting test will reveal the presence of even a slight curvature.
2. When both the work surface and the tool are clean, that is to say, uncoated. This system is safe for the tool only when the work has been rather finely finished and is, therefore, quite smooth. The accuracy of this method is far superior to that of the preceding one due to the absence of drag induced by the spotting medium.

In either case, the STRAIGHT EDGE is laid on the work surface. Then a finger is placed at one end of the tool, and an

attempt is made to spin it. The gage will start to rotate if the work surface is convex. By observing the movement, the high point is then ascertained.

When the high or pivot point is approximately at the center of the surface, the tool will rotate equally well when turned from either end. However, if the high area is well off-center, the STRAIGHT EDGE will be easier to push from one end and more difficult from the other. By propelling the tool from the end more readily moved, the location of the pivot point may be determined with greater accuracy. If there is any tendency towards rotation, the area immediately adjacent to the pivot point is scraped over once, and the STRAIGHT EDGE is again applied.

The sensitivity of the Pivot Test is such that it will reveal curvature in the work surface impossible to detect by ordinary methods, such as with marking compound transferred by normal spotting procedure. Thus it will disclose on a work surface the presence of a curvature more minute than the thinnest film of marking compound.

Incidentally, it is also possible to perform the Pivot Test utilizing a SURFACE PLATE.

Sec. 22.4
Three Papers Test

The Three Papers Test is a check for flatness that has a wide application on many types of surfaces. It is often employed in testing the flatness of the top of grinder tables and the ways of lathes, planers etc.

The apparatus for the test comprises three small strips of paper of identical caliper, although in some set-ups Precision Gage Blocks are substituted. A hardened and ground steel straight edge is also essential equipment.

The procedure to be adopted when testing a surface for flatness by this system, is as follows:

Three strips of paper are laid in a widely spaced row across the surface being checked as represented in Fig. 22.3. The steel straight edge is positioned so as to span all three slips. With the thumb and finger the operator tries to pull out the papers a short distance one at a time. This is repeated as often as necessary

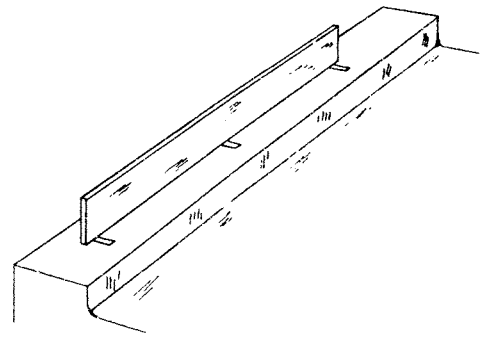


Fig. 22.3 General arrangement of apparatus for Three Papers Test.

comparing the drag of each slip. If all three display an equal resistance to the pull, this conveys the information that the surface is flat. On the other hand, if one evidences more or less drag than the other two, this denotes an uneven surface and also indicates the location of the curvature or direction of the tilt. Due to the sensitivity of the fingers this is an extremely reliable test and in consequence is frequently used.

When making this test the operator should not be satisfied to extend the row of paper strips in just one direction. If the size of the surface permits, the accuracy of the test can be enhanced by laying the paper strips in rows, longitudinal, transverse, and oblique.

Sec. 22.5
The Shake Test

In effect the Shake Test is a method of duplicating to a degree the working pressures which will affect the surface or part, in question, when the machine is placed in operation. The simulated pressures are easily and quickly applied and for that reason the test is helpful to the scraper in checking the accuracy of his work.

For one reason or another, some surfaces are very difficult to spot properly. Either the spotting tool is not adaptable to the work surface or limitations of space for proper manipulation may be a factor. Regardless of the cause, it means that the operator is not always certain that he is scraping the surface flat. When this uncertainty prevails, and especially if

difficulty occurs in fitting one member to another, it is advisable to make a "shake" test.

Basically the method involves testing a sliding or rotating member for convexity or side play with reference to a stationary member. Its application is not restricted to sliding bearing surfaces but can be used also to test shafts, spindles or rams.

Essentially, the procedure consists of applying an intermittent or sustained force by shaking or prying the member and judging the displacement in relation to its mateing part. The degree of movement is estimated by the sense of touch or, more accurately, gaged by instrument. The check is made at two or more locations and is repeated until the question is decided.

The Shake test is appropriate when the position of the bearings to be tested is unfavorable for the utilization of the X Test or Pivot Test. It is performed most efficiently by the co-ordinated efforts of two men, particularly if the member involved is massive.

In conducting the Shake Test the first requirement is that it must be performed under actual operating conditions. To illustrate the procedure an imaginary case involving a major rescraping job will be utilized. In the following demonstration, we shall employ as an example, a Vertical Milling Machine, (Fig. 28.1), and test the guided slide of the knee member for convexity. With the column laid horizontally, the knee is placed in position, and the gib is inserted and adjusted for tight sliding pressure. Next the knee is rocked back and forth. In short, an attempt is made to twist the member. While this operation is being performed by a helper, the scraper should place the fingers of one hand partly on the column and partly on the knee i.e. over-lap. Then if any side-play is present it will be sensed through the fingers.

In case the member is too large to "jiggle" conveniently by hand, a leverage may be obtained by roping a length of 2" x 4" timber to the knee as shown in Fig. 22.4.

While an assistant attempts to twist the member by moving the lever back and forth, in the direction shown by the arrow, the operator tests for any signs of "rock" at the top of the knee and then again at a similar position at the bottom. If the fingers detect only a slight amount of move-

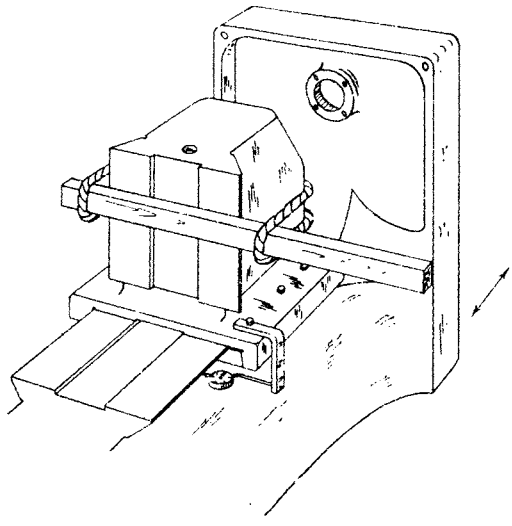


Fig. 22.4 Using DIAL INDICATOR to measure "rock" of members when executing Shake Test.

ment, this is due to a shift in the oil film and is permissible. A greater motion indicates the existence of a convex surface on the knee.

Until the operator gains experience in estimating movement by his sense of touch, all testing should be done by instrument. This is desirable because the sense of touch is highly developed in most people. Therefore, the novice is liable to err by assuming that the dislocation felt is excessive. While developing this knack it is best to rely on a DIAL INDICATOR. By fastening the instrument to one of the members, with the contact button touching the other member, variations in the DIAL reading will disclose the degree of "rock."

The direction in which the knee member is oscillated cannot be aimless if any valuable information is to be gained. Furthermore, the placement of the DIAL button must be co-ordinated with the jiggling. For example, by securing the device to the knee and placing the button in contact with the column gibway, as shown in Fig. 22.4, we can by working the wooden lever in the direction indicated, determine from the reading whether the knee guided slide is convex.

Sec. 22.6
Wind or Twist

Wind or twist is one of the most

serious faults that can affect bearing surfaces. It is in reality a warp of one or both ways of a member. Usually it is spoken of as affecting the bed or main casting but it is often located in slides, especially of members long and slender.

Due to the importance of this term and the frequency it will be encountered, it might be well at this point to digress for a moment in order to describe briefly what a "wind" is. It means a warping away from a true flat plane, generally most pronounced at the ends of a surface. To obtain a truly flat plane, "wind" must be totally eliminated. The effect of a twist is to bring about a misalignment of machine parts. It also impairs the work output of a machine.

Sec. 22.7
Methods of Detecting Wind or Twist

Where long surfaces are involved, "wind" can be a very serious problem and complex systems are required to trace it. The taut wire method and the telescope and target method belong in this category.

When the member is short to medium length it can be effectively tested for twist by utilizing the X test described in Sec. 22.2.

Sec. 22.8
The Taut Wire Method

The degree of wind in a long bed can be determined accurately by utilizing a tight wire and microscope. Fig. 22.5 represents this familiar manufacturing test.

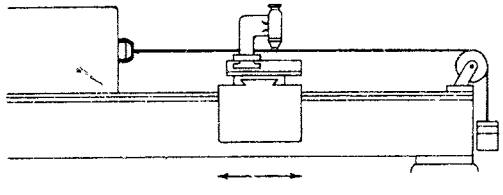


Fig. 22.5 Diagram of Taut Wire and Microscope System of testing for "wind".

At a convenient height, a taut steel wire is stretched approximately parallel with the ways of the bed. Two microscopes are arranged on the sliding member. One microscope is set to test the alignment in the vertical plane, the other in the horizontal plane. (See Note) After the instruments have been positioned they should not be moved during any portion of the test.

The sliding member is pushed to one end of the bed and the wire is adjusted so that it aligns, vertically and horizontally, with the cross-wires in the microscopes. A similar adjustment is made at the other end of the bed.

The sliding member is next pushed to intermediate positions along the bed ways. By observing the vertical and horizontal deviations of the cross-wires of the microscopes with reference to the taut wire during the traverse, the degree of wind in the bed is measured.

Sag in the wire at any point between the supporting ends can be calculated accurately. Allowance is made for sag when making observations at various positions along the bed.

The vibration of the wire (which increases with the length of the bed) limits the usefulness of this test. It can be controlled to a certain extent, however, by damping. This is accomplished by attaching one end of a number of small strips of paper to the wire. The opposite ends are immersed in oil containers arranged under the wire at spaced intervals. Bed lengths of 50 feet or more can be tested easily without additional precautions.

The wire size should be about 0.004" diameter, which corresponds to a 6/0 music wire gage. Special care must be taken that the wire is free from kinks which introduce errors.

When the Taut Wire Test is utilized for testing between centers, such as on a lathe, the wire is lined up co-axially with the centers. This can be accomplished easily by inserting plugs in both the headstock and tailstock spindles. A hole the diameter of the wire is drilled in the middle of the plugs. The wire is made taut in any convenient manner either by weights or by a screw and nut arrangement. When using the latter, be certain that the wire does not twist while tightening it.

NOTE:
Microscopes are available which through a series of prisms can measure both the vertical and horizontal displacement of the wire without changing the position of the instrument.

Sec. 22.9
Telescope & Target Method

Another testing method for wind involves the use of a telescope and a target. The telescope remains fixed on the stationary member while the target moves with the sliding member on which it is fastened. Vertical and horizontal deviation is measured by sighting as the target moves from end to end of the bed.

Sec. 22.10
Tests for Parallelism

Alignments cannot be secured unless ways and slides are parallel. To verify this condition it is common practice to utilize an indicating jig and attached DIAL INDICATOR (See Fig. 16.19) This apparatus should be employed at frequent intervals during the scraping process. If carefully handled it will provide an accurate indication of parallelism. However, when reconditioning precision tools absolute proof is required that the ways and slides are straight and parallel. Therefore, the more elaborate tests described in the following sections are also used.

Sec. 22.11
The Sliding Member Test

Essentially, the purpose of this test is to indicate the parallelism of the ways or slides of a machine member. It is equally effective in determining the parallelism of both square edge and dovetail constructions. The test is widely applied to all categories of machine tools having these types of bearing whenever the weight of the sliding member is not excessive hindering easy handling.

A few typical applications on which the Sliding Member Test could be applied to slides moving on ways, and ranging from the specific to the general, are as follows:

1. A milling machine knee on a column
2. A milling machine saddle on a knee
3. A milling machine table on a saddle.
4. A lathe cross slide on a lathe carriage
5. Any construction comprising a gibbed or bracketed member.

The Sliding Member Test should be performed whenever the available jigs, gages etc. are not thought accurate enough to test the ways with satisfactory precision. It is invaluable also for confirming or disproving the accuracy of components or sub-assemblies scraped independently.

It is a simple matter to prepare for the test. The sliding member is assembled on the freshly oiled ways of the stationary member, and the gib is inserted and adjusted for sliding pressure. Next the sliding member is moved by hand from end to end of the ways of the stationary part. Use is made of the touch or sensitivity of the hands to detect any looseness or bind, either of which is a certain indication of non-parallelism.

Whether or not the revealed defect is in excess of the accepted limits can be estimated with fair success after experience is gained. But it is sometimes advisable to measure this value closely because all machine tools can operate efficiently within a small margin of error. Perhaps the most convenient system is to attach a DIAL INDICATOR to the sliding member and bring the plunger button of the device in contact with one of the ways being traversed.

The DIAL reading will disclose if parallelism is within the permissible tolerance. The DIAL is actuated if a bind squeezes out the film of oil between the members bringing the two members into closer contact. There is no comparable reading if slack is evident in the direction being traveled. Consequently, the operator must re-adjust his gib for sliding pressure at this farthest extremity and note the reading of the DIAL on the return movement. Incidentally, a sensitive instrument is required for the gaging since it must be responsive to even slight changes in pressure.

The method described above is sufficiently accurate for nearly all purposes and is much quicker to use, but the following method should be adopted where a higher degree of precision is wanted. The ways which are to be tested are cleaned of oil and coated with a thin layer of marking compound, such as Red Lead deposited by Evaporation. Then the sliding member is re-assembled and moved along the ways. The uniformity in coloring of the marking compound on the ways after a few traverses will be an exceedingly responsive and reliable test for parallelism. If variations in coloring occur, a correct interpretation

thereof will indicate the direction of divergence of the ways. (See Sec. 10.11) A trained observer will also be able to make an approximation of the amount of error.

In those cases where the gib piece is fastened to the stationary member, it is the slides of the sliding member which must be parallel. The previous remarks on the Sliding Member Test then apply with equal appropriateness to the latter member.

As we have pointed out above, if sticking or binding is experienced, when performing the Sliding Member Test, nonparallelism is indicated. Since this defect must be corrected before proper operation of the machine can be expected, it raises an important question for the novice scraper, namely: "On which member, stationary or sliding, shall the correction be made?" The inflexible rule is: "Rescrape the bearing surfaces of the member which is not gibbed." These may be either the ways of the stationary member or the slides of the sliding member. Follow this by retouching the gib piece, if it is either the tapered or angular flat type. The straight flat gib does not require attention because the screws will provide all the adjustment necessary.

Sec. 22.12
Testing with a Water Level Surface

A water level surface is sometimes utilized when it is desired to test the following:

1. The parallelism of ways in the vertical plane.
2. The levelness of ways.

Testing Parallelism of Ways.

The application noted above is useful to the operator in testing the parallelism of long ways such as are found on planer beds. The procedure is as follows:

The ends of the V's are plugged with clay and connected to each other by piping or hose of ample diameter, as shown in Fig. 22.6. The V-ways are partly filled with water which automatically assumes a level position of equal height in both V-ways.

Preceding the operation described above, the scraper should make up a V-way template about 8" long. (See Fig. 22.7) A

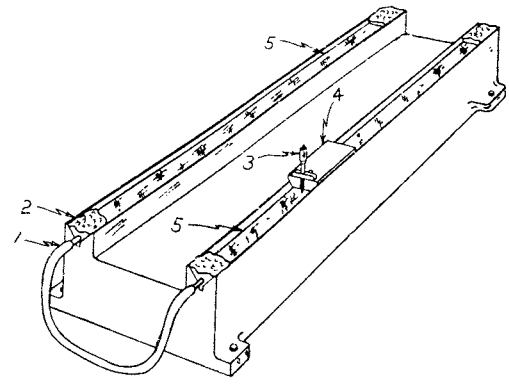


Fig. 22.6 Application of Water Level System for testing parallelism of V-ways in the vertical plane.

(1) Pipe and connecting rubber hose (2) Clay (3) Depth micrometer (4) V-gage (5) Water level

narrow groove is cut into one end of it, so that the measuring rod of a depth micrometer can be inserted. This groove provides the base of the instrument with an ample platform for stability. The lower portion of the V-template is machined away to prevent contact with the water. After being machined, surfaces (A) and (B) are carefully scraped to fit the V-ways. (For methods refer to Sec. 12.10) The top surface (C) is also hand scraped so that the micrometer measuring rod will bisect the template, as represented in Fig. 22.7.

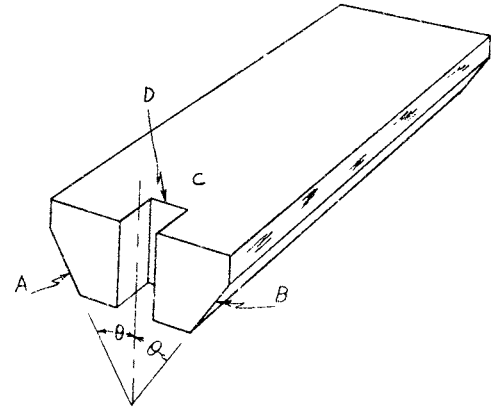


Fig. 22.7 Showing form of V-gage used for testing with Water Level System.

(A) Scraped surface (B) Scraped surface (θ-θ) Angle (C) Top surface (scraped) (D) Slot

The tip of the measuring rod should be lapped square with the stem.

Returning to Fig. 22.6, we observe the method of using the template. It may be placed in either V-way with the depth micrometer set on top. The measuring rod is adjusted until the tip just touches the water. Measurements taken at both ends and at intermediate points of one V-way must be identical. Similar measurements made on the other V-way from end to end must also be identical. Any deviation in either reading indicates non-parallelism in the vertical plane.

Checking the Levelness of the Ways

The second application of the Water Level Method is sometimes employed to learn if the ways of a bed are level. This system is adaptable to all forms of bearings such as Vees, inverted Vees and flats. Fig. 22.8 illustrates the set up.

Two U or I beams are placed on horses alongside the bed, one at either end. They are connected together with a hose of adequate proportions. After the ends of the beams are stopped up, water is poured into one trough. It flows through the hose and rises to a uniformly level position in the other trough. A rigid support, extending out over the water channels, is bolted to the table or carriage on top of the bed. A depth micrometer is fastened to the support and adjusted downward until contact is made with the water. Readings are taken at both ends of the bed. The difference in readings will represent the degree of slope of the bed ways. This method is useful in checking the alignment of long beds during erection.

With both of the tests discussed above,

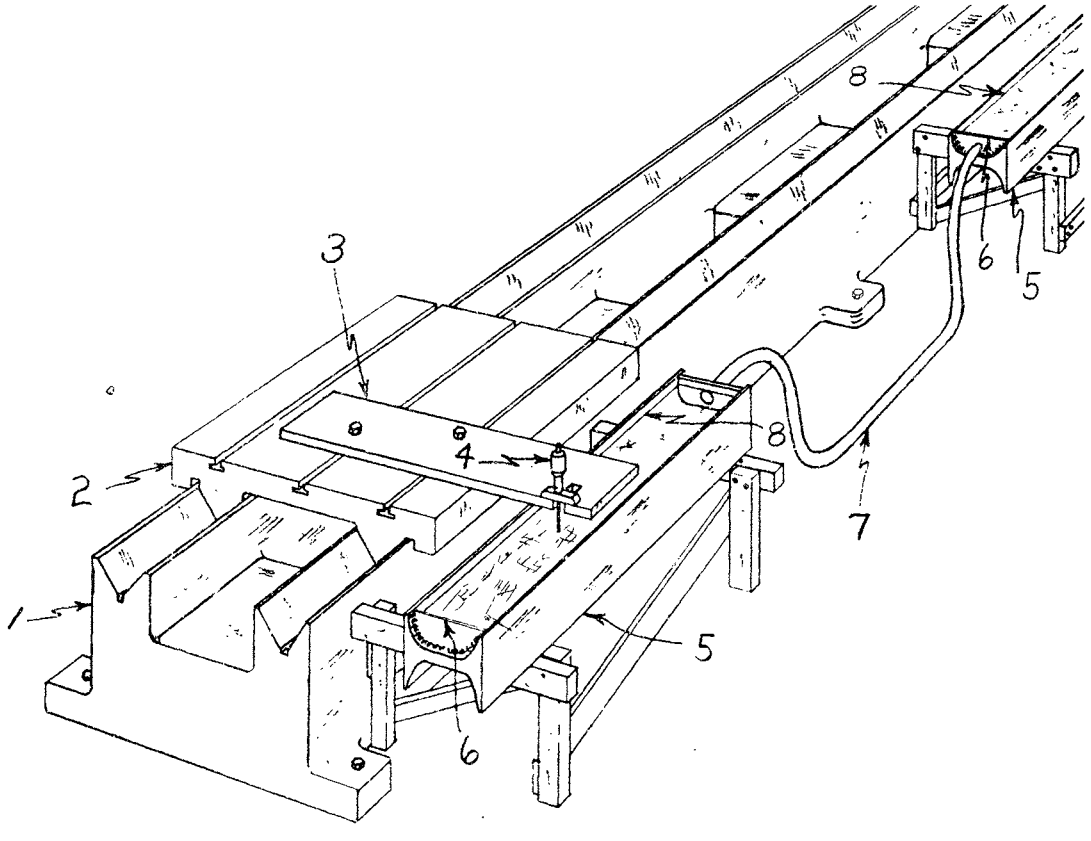


Fig. 22.8 Applying the Water Level System for testing the levelness of V-ways.

(1) Bed (2) Table (3) Plate bolted to table (4) Depth micrometer (5) I-beams (6) Welded end plate (7) Connecting hose (8) Water level

good lighting is necessary so that the operator can observe clearly when the measuring tip just touches the surface of the water. Since water has a certain amount of surface tension, care must be exercised not to depress it. If the surface tension of the water is broken, capillarity will cause the liquid to climb the rod to above the water level. This necessitates withdrawing and wiping the rod dry before another attempt is made.

Sec. 22.13
Capacitive Micrometer

The capacitive micrometer, which is a new development in electronics rapidly coming into general use in the machine shop, can replace the conventional depth micrometer when conducting the Water Level Test. This instrument is essentially a condenser-oscillator arrangement possessing high accuracy. It can be applied to a moving mechanism to obtain continuous readings whereas the standard micrometer can give readings only at intervals when at rest.

When used as a component in a set up for indicating parallelism or levelness of ways, the capacitive micrometer should be mounted on either the V-template or on the sliding member mentioned earlier. The condenser plate is adjusted close to but not touching the water. If the distance to the water varies, as the device is moved along the ways, the frequency of the oscillator is altered. This fact is noted in the position of the dial hand on the indicating meter.

The principal advantage of this device is that preliminary calibrations of this instrument are unnecessary when testing for either parallelism or levelness. In determining these matters, we are concerned mainly with the existence of a deviation and not necessarily with the amount. If we assume, for example, that at the first test the meter recorded 10 units of variation from levelness between ends of the ways; and that, let us say, after one scraping cycle the deviation was reduced to 8 units, the scraper would then know that about four more scraping cycles of equivalent depth would be required to approximate levelness. Since all scraping alignments are of necessity a cut and try proposition, the adoption of this device does not increase the difficulty of the test. Furthermore, no special technical knowledge is required to employ it successfully because it is a comparatively simple mechanism to operate.

Sec. 22.14
Fitting

The process by which a sliding part is prepared to operate smoothly on a stationary part is called fitting. Components so matched are designated as mateing members.

A slide is said to be well fitted to its way if three conditions are satisfied. First, it requires stability. This means the slides (and ways) must be flat and show no traces of either concavity or convexity. Second, it should possess the characteristic of free movement. This refers to the degree of parallelism in the bearing surfaces of the mateing members. Insufficient accuracy in this regard can cause sticking. This term also relates to the quality of bearing which if inadequate can result in a hesitating movement. For example, a non-uniform bearing quality on the ways and slides of precision grinding machines may induce chatter. Third, it must have area contact with the way in order to retard abrasion and prolong its normal working life. If this property is absent a line contact automatically results which accelerates wear and leads to premature misalignment of the assembly.

The fitting of flat slides to flat ways is elementary. If dovetails are involved, more care is needed as the angular values must be closely matched for successful operation of the assembly.

Ways and slides of both the V and inverted V type are also difficult to match with each other. Not only must angles be matched they also must be so formed that a perpendicular line will bisect them in order to equalize wear between the sides of the V.

Sec. 22.15
Test for Fit

To test the fit of slides to scrape-finished ways, the first step is to coat the latter surfaces with a film of marking compound. The slide is placed on top of the stationary member and is moved by

hand, back and forth, sufficiently to transfer the medium. After the sliding member is removed, the markings on the slide are inspected. All indicated high spots must be scraped away. This routine is repeated as often as is necessary. The final inspection is accomplished with the very thinnest coating of marking compound.

The slides are deemed adequately fitted when they possess the desired degree of bearing quality, maintain overall area contact with the mateing ways, and evidence no sticking or other signs of non-parallelism in the course of a Sliding Member Test.

The inexperienced operator should be warned that fitting slides to ways is not, as some believe, an automatic procedure entailing no possibility of error. On the contrary, using one member to spot another creates its own problems. In the first place, the part being spotted may be, and often is, quite heavy. Manipulating the piece is physically tiring and only very conscientious workmen will persevere at it for any great length of time. Furthermore, the pressures induced by the massive member may cause inferior marking compounds to smear and run. Consequently, care must be exercised to select the right type for the job and to spread only the minimum thickness of film.

Another detrimental influence may be convexity. A slight degree of this on the bearings of the part being pushed and pulled may induce a rocking action which causes false markings. To avoid being deceived by the appearance of such fictitious markings which imply over-all area contact, it is advisable to alternate the spotting with a STRAIGHT EDGE, SURFACE PLATE or other appropriate gage. This procedure will serve as an additional assurance that the surface is truly flat.

The use of a perfect tool while spotting a bearing surface positioned in the ideal horizontal plane will improve the chances for accurate results. But the operator should not be too positive that such a surface has an area contact even when it shows a uniform, over-all marking from both the tool and the mateing member, which are used alternately.

To settle this point if there is some question in the mind of the scraper, the middle portion of the bearing surface should be scraped very lightly during one cycle while the ends are left untouched. If no appreciable change is apparent in the markings following the next spotting cycle, this is proof that the surface neither is, nor was, flat. In other words, the localized scraping has improved the work surface to some extent, though to achieve flatness more of the same is needed in this restricted place.

On the other hand, if the markings do vary in size or coloration, with the ends showing a better bearing than the middle, it signifies that the surface was flat originally and that the experiment, by producing a slight concavity, has caused a minor setback. Now that all uncertainty on this score has been resolved, the surface can be quickly finished.

Sec. 22.16
Area Contact

Area contact is defined as a condition wherein the bearing surfaces of the sliding member have complete overall contact, from side to side, and from end to end, with the ways of the stationary member. This condition is a prerequisite to the proper functioning and durability of the slides and ways of matching members.

An area contact is a basic requirement of all bearing surfaces. All references to bearing quality imply a uniform, overall bearing or area contact. Special circumstances sometimes dictate a modification of this rule, but there is always a logical reason for such exceptions. (See Compound Bearing Sec. 19.11) The quality of bearing will be determined by the type of service for which the surface is intended.

Unless this close area contact prevails, line contact automatically results. The term line contact is suggestive and signifies an absence of intimate overall bearing between two surfaces. It is objectionable because it hastens the rate of abrasion. Accelerated wear induces the formation of a groove or channel in the less durable surface. The result is a rapid deterioration of the existing alignment between members. This alignment can be restored only by corrective treatment of the appropriate bearing surfaces.

Sec. 22.17
Test for Area Contact

Whether or not a newly scraped, apparently flat surface has area contact with its mateing surface cannot be detected by instruments during alignment tests. In fact, perfect though transient alignments are equally possible with members having line contact as with those having area contact.

It is the practice of some operators to probe with a .0015" feeler gage to ascertain whether there is over-all contact between the bearing surfaces but this is unsatisfactory for precision work. The only thoroughly reliable method of discovering whether two bearing surfaces have area contact or line contact is performed by utilizing a marking medium.

To provide an indicating medium, a quantity of marking compound is spread thinly on the ways of the stationary member. Then the sliding member is placed in operating position, with gib adjusted to the working pressure. By moving the sliding member by hand, or by power, from end to end on the ways, markings are produced on the slide. The marking compound coating the ways is also altered correspondingly.

By an analysis of the markings on both the ways and slides the operator can determine the condition of the bearing surfaces. A pattern of markings, uniform in coloration and overall distribution, indicates an area contact. On the other hand, a thin line of compound on the slide or a streak on the way denotes a line contact. Re-reading of Sec. 10.11 and Sec. 10.19 (Interpreting the Markings) may be helpful.

Sec. 22.18
Problem in Producing Area Contact

In order to produce area contact, bearing surfaces should be scraped so that both ways of the stationary member support a proportionate share of the weight of the mateing member. The problem of achieving area contact between ways and slides involves no unusual difficulty provided the design of each set of ways (or slides) is similar. That is to say, matching two flat slides to two flat ways, or two inverted V-slides to two V-ways is a simple process of fitting. However, when the two bearing surfaces of a member are dissimilar, a new problem is posed.

Assume for example, that we are trying to secure this close contact between the flat way and inverted V-way of a lathe bed and the flat and V-slide of a tailstock base. The solution in practice is to scrape the bed flat way level in the transverse and longitudinal directions. Concurrently, the inverted V-way of the bed is so scraped that a perpendicular line will bisect it. This method is discussed more fully in Sec. 25.16. Thus wear and pressure will be equally distributed between the flat way and both sides of the inverted V.

After the ways have been prepared as a template, the slides of the mateing member, the tailstock base in this instance, can be fitted to them. This requires some care if the top of the base is not to be tilted and lose its alignment. The appropriate procedure is to scrape approximately 50% deeper on the flat bearing than on the V in order to keep the top surface of the member level. See Fig. 22.9. This technique serves to maintain the top surface in a plane parallel to the original factory surface.

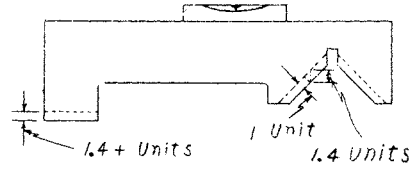


Fig. 22.9 Diagram showing necessity of heavier scraping on Flat slide than on Sides of the V. A ratio of 1.4 to 1 will maintain the top surface level while attaining bearing quality.

To accomplish this result a thickness approximating 1.4 units of metal is removed from the flat slide to every 1 unit of metal scraped from a 90° V-slide. Refer again to Fig. 22.9. The ratio would vary proportionately for V-slides of different angular value.

Sec. 22.19
Judging Bearing Quality

The appearance of a scraped surface, no matter how expertly the job seems to have been done, is no criterion by which to judge its flatness and bearing quality. It is such a simple matter to camouflage

the work piece with what ostensibly are legitimate scraping marks, that the uninitiated are easily deceived. Only an expert is qualified to judge results and even he cannot be expected to distinguish spurious scraping marks from the genuine merely by looking at them.

Shops which consistently maintain a high grade output do not rely at the final test on a mere visual inspection of the colored markings when evaluating the quality of the scrape-finished surface. For instance, it is standard practice, when the job has been completed to the satisfaction of the scraper, to call in the inspector and receive an O. K.

The procedure normally followed is for the mechanic to spot the surface one final time while the inspector closely watches every move that is made.

When checking bearing surfaces the safest procedure to adopt is the one followed by the machine tool builders when passing on the quality of their output. It consists of a careful scrutiny of each and every step of the complete spotting cycle. Usually the operator who has performed the work on the machine manipulates the spotting tool while the inspector observes his actions. It is essential that all the test procedures be executed accurately. A slip shod performance during any part of this routine can produce markings that will give a false impression of the quality of the work.

This spotting must be performed under rigidly controlled conditions. It is known from experience that the mere appearance of a nicely finished bearing surface, having uniformly distributed bearing spots, is not conclusive proof in deciding whether that surface is flat. It is additionally necessary to have information concerning the following points before this characteristic can be determined with certainty.

1. The inspector must be absolutely sure that the spotting tool, or surface of a mateing member used to transfer the compound, is flat and in good condition. In other words, there must be some standard of comparison whose accuracy is unquestioned.
2. The inspector must be certain that the proper spotting technique is employed. This means using a tool appropriate to the work, correct in size, and manipulated expertly. Further consideration is given to the working position i. e. convenient or cramped; to absence of hand pressures; and to the thinness of the marking film.
3. The tool must be laid directly on the work surface, not slid. Similarly, in removing the tool, separation should be abrupt, again without sliding.
4. The length of the spotting strokes should be short. Long, sweeping strokes which induce false markings are to be avoided.
5. Frequent use of the Pivot Test and other appropriate tests to disclose a convex surface is customary.

When these requirements are complied with, the expert knows that the work surface has been properly spotted. However, in addition there must be a close inspection of the markings before a final judgment can be rendered. Consideration must be given to the following points.

1. It is essential for the bearing spots to be of the same coloration.
2. Distribution of the bearing spots must be uniform over the entire surface except, or course, in the case of a deliberately planned compound bearing surface.

Only after these points have been observed and analyzed by the expert can he form an opinion as to the condition of the work surface. The non-expert is in a dilemma from start to finish simply because he does not have the experience and knowledge to enable him to check the several essential factors.

If the inspector is satisfied that the final spotting, as it was performed in his presence, complied with all parts of the outline given above, then and not before, will he accept the markings at face value. The appearance of the markings can be judged as a true indication of the bearing quality and flatness of the surface only when all facts pertinent to their formation are known. From the foregoing it can be seen that the scraper who operates without supervision and O. K's his own output is obligated to be doubly conscientious when spotting the work surface that final time.

Sec. 22.20
Surface Finish

Surface Finish, as distinguished from surface bearing quality, means the average depth of the surface depressions below the plane of the bearing spots. Their average depth is the measure of the quality of the Surface Finish.

The importance of Surface Finish varies according to the kind of machine tool. It is not so consequential on machines having gibbed members, except as regards appearance. But on tools not gibbed, such as precision grinders, a good surface finish is essential. The reason that this characteristic is so important on precision grinders is that it largely determines the viscosity of the oil that may be used on this type of machine. The minute depressions filled with oil during normal operation of the machine, serve as lubrication reservoirs. This is discussed more fully in Sec. 24.4.

Surface Finish is produced by the hand scraping process simultaneously with the development of bearing quality. As the bearing quality improves with the increase in the number of bearing spots per square inch, the penetration of the cutting blade necessarily is shallower with each successive cycle. There is an accompanying improvement in Surface Finish because the depressions surrounding each bearing spot become progressively less deep. Incidentally, studies have been made which indicate that hand scraping will produce a quality of Surface Finish equivalent to that attained by high grade surface grinding.

Ordinarily, in reconditioning work, the operator will not trouble to measure Surface Finish, except possibly on precision grinders. However, an estimate is not difficult to make. One simple method utilizes a sensitive DIAL INDICATOR, calibrated in "tenths". After attaching it to a SURFACE GAGE of good quality, the apparatus is set on the bearing surface to be measured. The DIAL button, which must be quite pointed, is placed in contact. Oscillations in the DIAL pointer occur as the button drops into and climbs out of the minute surface depressions when the device is pushed forward by hand. From the fluctuations of the pointer, some idea of Surface Finish can be gained.

To measure Surface Finish accurately a Profilometer or similar surface measuring instrument calibrating in micro inches R. M. S. is necessary. The Profilometer can distinguish between two surfaces varying in smoothness by a millionth of an inch, as readily as the hand can distinguish between a piece of plate glass and a gravel road. This instrument is a diamond tipped device which probes into scratches or hollows. Its point has a contact area of only 3×10^{-10} of a square inch (.0000000003")

Sec. 22.21
Measuring Back Lash on Gearing with a Dial Indicator

After a rescraping job on a precision grinding machine is completed and all the ways are correctly aligned, it is advisable to check the amount of back lash between the rack on the work table and the pinion gear in the bed casting to which the handwheel is attached. This procedure is especially advisable in those cases where the ways and slides were badly worn and it was necessary to remove much metal to restore alignments and recondition bearings. Lowering the surface radically tends to cause the gearing to bind. This would prevent area contact between the ways and slides.

A quick and simple method of checking back lash is shown in Fig. 22.10. This

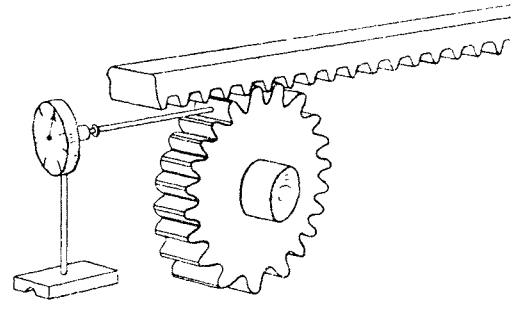


Fig. 22.10 A method of checking back lash between rack and pinion. Hand wheel is attached to this pinion gear. Oscillate hand wheel without moving table. Tolerance allowed between .008" and .015".

test is quite practicable when applied to the smaller grinding machines. The essential equipment consists of a DIAL INDICATOR mounted on a heavy base and a

length of 1/8" drill rod. The rod is placed against one tooth of the pinion gear, meanwhile holding the other end against the contact button of the DIAL.

To perform the test the hand wheel is turned consecutively, clock-wise and counter-clockwise, as far as possible without causing the table to move. The actual back lash is indicated by the change in the DIAL INDICATOR reading. Incidentally, one large manufacturer of hand feed surface grinders recommends a back lash of between .008" and .015" when measured by this method.

Another practical test for back lash, and one often used, involves introducing a strip of paper between the rack and pinion. If the paper is thoroughly crimped, but not cut, in passing through the gearing as the hand wheel is turned, it is proof that the gearing is neither binding nor excessively loose.

Chapter 23

FACTORS IN RECONDITIONING

Elementary technical operations of scraping procedure, even if thoroughly understood and correctly applied, are not sufficient in themselves to effect a reconditioning job on a machine tool. Several additional principles are involved which must be converted to use, where called for, to insure success. The foregoing chapters have been concerned principally with the mechanical routine of hand scraping. In this chapter we shall discuss a few related aspects of reconditioning that are required knowledge if competent work is to be performed. The intent of this chapter is to familiarize the operator with these less obvious but equally important problems and to offer solutions to some questions which frequently arise.

Sec. 23.1
Machine Tool Inspections

The fundamental operation, prior to reconditioning a machine tool, is inspection. "What is wrong?" and "Why?" must be correctly answered before the scraper can safely take a single cut on a worn bearing surface.

When production machine tools are involved, one good method of inspection is to check the finished product turned out by the machine. The inspection of the finished work pieces ordinarily is performed on a day to day, hour to hour, or even piece to piece basis. Inability to meet specifications is noted immediately. There may be any number of causes for this deficiency, such as an incompetent or careless machine operator, faulty tooling, etc. These factors being most easily corrected, will undoubtedly be checked first. However, a consistent failure to deliver an output of the required accuracy suggests a below standard machine. In such a case, it should be turned over at once to Maintenance whose responsibility it then becomes.

Often the maintenance department is expected to diagnose the trouble from an examination of only a few inaccurate work samples. From a consideration of the design of the piece part, the specific operations involved in manufacturing it can be easily established. By thus limiting the field of search, the analysis of the bearing surfaces responsible can be both discriminating and efficient. The more information available about the machine (facts concerning operating conditions, strains, abuse or wear) will assist the scraping operator in determining more intelligently which surfaces or alignments need special attention.

When a complete rebuilding of the machine is out of the question because of the time factor, the ability to trace down the primary cause of the difficulty permits localized treatment for quick repair. This, obviously, will not restore all operations of the machine to first class condition, yet it may well return the machine to service on a fairly satisfactory basis, without undue delay. Sometimes even the relatively simple replacement of a worn gib piece with a well fitted one will noticeably improve the efficiency of a member. The reader should not misconstrue the foregoing to mean that a general overhaul can be indefinitely postponed. Our point is that finding the key to a failure and setting it right will, in many cases, provide adequate, though admittedly temporary relief.

If an analysis indicates a mechanical failure, involving shafting, gearing or a hydraulic system, the procedure to be adopted to correct the fault is not a proper topic for this book. This present discussion will deal only with the correction of alignments which affect the accuracy of the work output, when the source of the difficulty is traced to wear in the flat bearing surfaces.

Before a reconditioning job is started, the maintenance department must have exact information as to the proper alignment of the various members of the machine and the permissible tolerances. In

addition, the operator selected for the job must have the necessary skill, a thorough understanding of the procedures to be followed during the rescraping operations, and have available accurate tools and testing equipment.

Sec. 23.2
Visual Inspections

In addition to flaws disclosed in the rejected output of the machine, the physical state of the bearing surfaces can also be determined by other means. For example, a rapid visual inspection may be made of a bearing surface. This will disclose with reasonable accuracy its present shape and forecast the imminence of needed repair.

Obviously, the most accurate and positive measures require the dismantling of the machine and the use of tools and gages for alignment tests. When time is limited, or when the machine is presently producing a sufficiently accurate output, and no trouble is suspected, then a quick visual examination will serve to "get a line on" the situation.

There are two checks that may be made to ascertain the condition of the bearing surface. First, when the scraper tool marks are disappearing, it is indicative that the machine member is beginning to wear. Second, deterioration has reached the next stage when frosting or flaking designs, which are incised deeper than the tool marks, commence to lose their sharp outline. From this time on, attrition will be accelerated and the machine, as a whole, will deteriorate at a progressively faster rate.

Visual inspection will also provide information as to whether a machine in operation for a long time has warped by ageing, or sprung out of alignment from rough handling or improper leveling. Of course, as we stated at the outset, the only exact test is to use precision gaging tools, but a careful observation of the bearing surfaces will prove a satisfactory substitute. For example;

Under normal conditions of operation, the major proportion of the wear on most bearing surfaces will occur at their extremities. Thus over a period of time, a convex surface will be formed, having a higher or less worn area in the middle. Therefore, if clear indications of greater abrasion at the ends of the bearing surfaces are not discernible, it suggests that the member is warped.

Sec. 23.3
The Exploratory Examination

When the machine has deteriorated to a point where a complete overhaul is required, the operator will have the opportunity to make an Exploratory Survey of the condition of all bearing surfaces. Essentially this is a process of determining how much metal should be scraped from each surface of a member, so that it can be restored to a plane parallel to the original factory-new surface. If performed preliminary to reconditioning the machine, the Exploratory Examination will enable the operator to conduct the scraping job in an intelligent manner as contrasted with the haphazard measures which, otherwise, are only too likely to be adopted.

In actual scraping practice the operator will find that it pays him well in time saved to take a few minutes to make an Exploratory Examination of the machine he is about to scrape, with the purpose of noting what members are most seriously deteriorated. The necessary information is gathered by a careful inspection of all surfaces. If it is possible to obtain a few samples of the output of the machine, the operator often will be able to confirm his impressions. In many instances, alignment tests can be made which will disclose the total error. Finally, an analysis of all pertinent facts results in a decision as to how each surface should be treated. In a word, the misalignment is prorated among the various affected surfaces.

While it is true that performing the routine takes time, and occasionally the undertaking is unproductive of worthwhile results, nonetheless, in most cases some valuable clues are obtained. But even if nothing of importance is learned, not much time is lost. The effort spent in executing the Survey can be defended because it improves the chances of getting the work started right. The Exploratory Examination assists the operator in making a close estimate of the situation; the alternative is a wild guess which may be close but is more likely to be wide of the mark.

The technique of performing the survey

is given step by step in several places throughout this book starting with Sec. 27.15.

Sec. 23.4
Datum Point

From the standpoint of logical operations a foundation of some kind from which the scraper can make measurements, directly or indirectly, must be established. This foundation is called a Datum Point. After it is selected all components of the machine are aligned thereto. A Datum Point, then, is a position on a surface or part, on which to base the alignment of the several members. It is to the scraping operations what the center line is to the blue print.

The Datum Point changes outward appearance as it is found on different machines. For example, it may be the intangible axis of rotation of a spindle on a horizontal milling machine, in which case it may more properly be termed a DATUM LINE. On the other hand, it may take the form of two parallel ways on the bed of a lathe or grinder. Sometimes the horizon is utilized as the point of reference when the shape or position of an otherwise logical surface creates difficulties, or for any reason is inaccessible. The PRECISION LEVEL is the tool which then determines the accuracy of alignments. In these cases we would be technically correct in referring to the Datum Point as a Datum Plane.

Sec. 23.5
Selecting the Datum Point

A number of factors influence the operator's decision in the selection of a DATUM POINT. They are enumerated below:

1. If a surface is selected, it should be on one of the first, though not necessarily the very first, members scraped.
2. If a machine part such as a spindle, is available, the difficulty, or even impossibility, of changing its position is apparent and thus its axis of rotation will necessarily become the Datum Line.
3. If alternative choices are possible, the position which is handy for a direct check to the greatest number of surfaces is favored.
4. The Datum Point should be an important unit to the machine as a whole, one around which other members may logically be built.
5. The horizon is often utilized as the Datum Plane for a machine when the shape of the available members or surfaces, or their positions, render them difficult to adapt for this purpose. For example, where surfaces are so widely separated as to make it impractical to bridge across to check alignments with a DIAL INDICATOR, SQUARE, etc., the deviation from the horizon expressed through the medium of the PRECISION LEVEL is again the logical choice.

In practice, the scraping operator makes a careful survey of the machine and then selects the one surface or component that will be most suitable to him as a Datum Point. Usually the choice is not difficult to make because one feature is outstanding. After the final selection of the Datum Point, all members of the machine are scraped using it to determine their relationship one to another. In a word, their alignment.

Sec. 23.6
The Check Point

Sometimes a temporary Datum Point or Check Point is established for the purpose of locating, testing or preparing the Datum Point. When this transient usefulness is terminated, future measurements are made from the Datum Point.

This term, Check Point, has also another meaning. For example, if a surface has been scrape-finished and aligned to the Datum Point it can be used as a Check Point for other nearby surfaces. It is sometimes more convenient to do this than use the Datum Point. However, in the final analysis there can be but one and only one base from which to measure and this is the Datum Point.

Sec. 23.7
Using the Check Point

The practical application of the check point is considered elsewhere in a number of procedures concerned with the treatment of the several machine tools.

specifically in Sec. 28.37. In this connection, one statement rather frequently made is that a given surface is aligned to a check point rather than directly to the Datum Point. The only reason why this is done is to take advantage of the accessibility of the former. One drawback, though, is that it may be slightly misaligned with respect to the Datum Point. That is to say, a part or all of the alignment tolerance allowed has been utilized. This, however, should not discourage the scraper who is striving for a high degree of accuracy. All that is required to meet this situation is information as to the amount of misalignment and its direction, i.e., plus or minus. Knowing this, and making allowance for it, the operator can utilize the check point as freely and as confidently as if the test was made directly to the Datum Point.

Sec. 23.8
Alignments

We have concerned ourselves thus far with explaining the scraping of individual surfaces or parts. Though this unquestionably is important it does not tell us how to scrape groups of surfaces. Now it will be necessary to co-ordinate this information with the equally important subject of alignments. This introduces a new factor for our study.

One of the principal requirements in machine tool building is proper alignment of members. A machine tool or a production tool must be correctly aligned, or else it cannot perform accurate work. If members warp or their bearing surfaces become worn, alignments are lost. When such a situation arises, reconditioning will restore the tool to good operating order. Part of this procedure calls for scraping the bearing surfaces flat and providing a good quality of bearing finish. Equally essential is the placement of the various parts in proper relation to each other. This constitutes alignment.

Sec. 23.9
Basic Alignments

Speaking generally, a basic alignment is the theoretical or nominal relationship between surfaces and members, which for practical reasons is only approximated. In other words, it is the alignment which would be obtained if perfection were possible.

In theory, the various machine surfaces are fixed on or travel in a direction square with each other; or swing in a plane at a definite angle to another surface; or slide parallel to each other; or move according to some combination of the above. Thus the expressions "parallel with" and "square with" represent the theoretical basic alignment.

But in practice these principles are modified by practical considerations. First, and foremost, is the fact that placing every surface in perfect alignment with adjacent surfaces would be prohibitive from the standpoint of labor costs and time. Consequently, tolerances are permitted. Here is where a good knowledge of the machine and its intended function pays dividends.

Some alignments affecting secondary functions can be less strictly enforced. That is, a liberal tolerance is allowed. Other alignments influence operations of major importance and with these a closer tolerance is the rule.

The influences affecting alignment for which tolerances must be provided, and which are invariably present in some form in every reconditioning job, are as follows:

1. The combined weight of the work piece and the several components supported by a principal member.
   Although undoubtedly inducing some strain, this is a negligible influence on well designed, massively constructed machines.
2. Cumulative Error
   Cumulative error results from the misuse of permissible bi-lateral tolerances. By offsetting these tolerances one against the other (equalizing) cumulative error can be avoided.
3. The Working Pressure developed by the cutting tool
   This factor is of major importance in machine tool alignments. To offset Working Pressure advantage can be taken of the slight errors permitted in the alignment. To be effective these tolerances must be unilateral, that is, always in the direction opposing the working pressure.

Sec. 23.10
Tolerance

Tolerance, as the term is used in the scraping art, is the amount that the alignment of a machine member may vary from exact conformity to a selected dimension. In other words, tolerance is the allowable deviation from an exact relationship between two members or parts.

Since perfection is, practically speaking, unattainable, the inaccuracies allowed are definitely specified by showing the tolerances on the "Alignment Test Record Card." Thus the utilization of tolerances is a method of controlling the overall accuracy of the machine. They can also be used to good effect in making a machine perform better under load than would appear possible from the results of static tests. This is accomplished by assigning the tolerance in a direction opposing Working Pressure (Sec. 23.18)

Determining the permissible tolerance on each surface is the first thing to settle before tackling a job. If a Manufacturer's Alignment Test Record Card is not available, the scraper must adopt tolerances on the basis of experience and knowledge of what is required in accuracy of the parts with a view to their proper assembly and the smooth performance of the machine as a unit.

Sec. 23.11
Kinds of Alignment Tolerances

The tolerances given in the Manufacturer's Test Cards, may be classified in two categories, as follows:

1. Bilateral Tolerances. These are written in two ways:
   a. With plus and minus signs, as (±) .0005" in 12". This signifies that the deviation may be both in one direction and the opposite direction permitting, essentially, twice the amount of assigned error in the given length.
   b. Without signs, as .001" in 24". This means that the deviation may be both in one direction and the opposite direction. The total deviation, plus and/or minus, may not exceed the assigned error in the given length.
2. Unilateral tolerances. These are always written with the minimum or maximum in a specified direction, as 0" to .001" in 12", low point at rear.

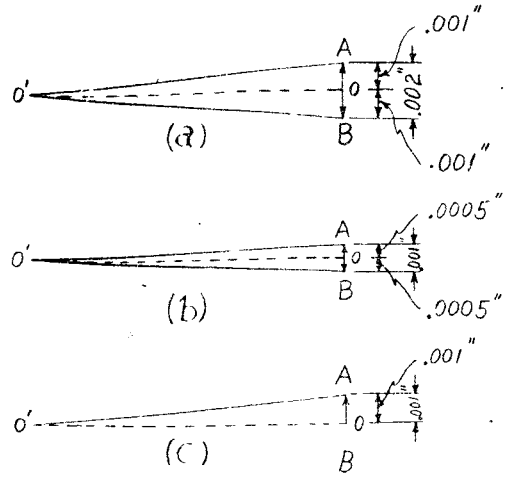


Fig. 23.1 Diagram showing types of tolerances. Arrows indicate direction in which tolerance may be taken.

(a) Bilateral tolerance with plus and minus signs (±) equals twice the specified tolerance. Example: Tol. (±) .001" in 24". A0 + 0B to equal total tolerance allowed. (b) Bilateral tolerance without signs. Example: Tol. .001" in 24". A0 + 0B to equal specified tolerance. (c) Unilateral tolerance taken only in specified direction 0A and not to exceed the amount allowed. Example: Tol. .001" in 24" (Rising in front)

Fig. 23.1 shows examples of these differences diagrammatically.

Each of these kinds of tolerances is important enough to warrant amplification. But before doing so, a few general observations concerning the use of tolerance signs are in order. For instance, the direction in which measurements are to be taken is left to the discretion of the operator, except when it is indicated on the Test Card by a statement or by a pointing arrow. When so designated the instruction must be followed exactly.

It should also be understood that once the starting point for a measurement is determined, the tests must be made from there to the stopping point without interruption. Furthermore, tests cannot be made from a mid-point and proceed half the required distance in opposite directions.

The distinction between the classifications of alignment tolerances is further clarified as follows:

Sec. 23.12
Bilateral Tolerance with Plus or Minus Signs.

A plus or minus tolerance indicates that within the reference length the allowable error is permitted to be on either or both sides of a zero-zero reading by the amount specified. For example, Fig. 23.2

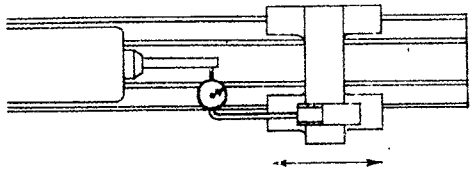


Fig. 23.2 Example of bilateral tolerance with plus and minus signs. (Top view) Lathe head stock alighment-horizontal. At end of 12" test bar 0 to (±) .0003".

shows the tolerance allowed for the horizontal alignment of the headstock of a tool room lathe. The recommended tolerance is stated as (±) .0003" in 12". A double headed arrow signifies that the test can proceed in either direction and the starting point will then be either at the spindle nose or at the free end of the test bar. This means that a DIAL INDICATOR which has been zeroed, at the starting point, could read a maximum of (+) .0003" at any point on the test surface (target) and a maximum of (-) .0003" at any other point, in traversing the reference length of 12". Thus actually a total deviation of .0006" is allowed.

Sec. 23.13
Bilateral Tolerances Without Signs

In a bilateral tolerance without signs the allowable error is permitted to be partially on one side and partially on the other side of a zero-zero reading, but the total tolerance taken on the two sides must not exceed the amount stated. Fig. 23.3, for example, shows the tolerance allowed for the rise and fall of a horizontal milling machine table in longitudinal movement. The recommended tolerance is .001" in 24". The double headed arrow calls attention to the fact that the test can be made in either direction with the starting point at any position which will permit a 24" table travel.

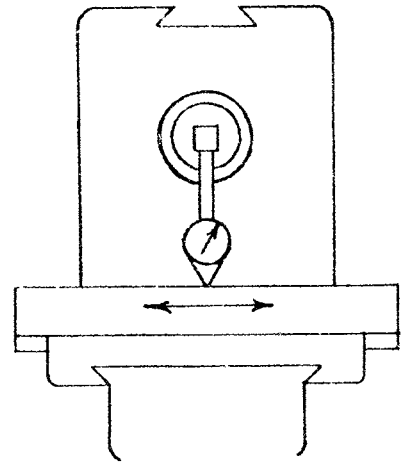


Fig. 23.3 Example of bilateral tolerance without signs. (Front view) Horizontal Milling Machine. Table top parallel with table movement. Max. .001" in 24".

This means that a DIAL INDICATOR, after being zeroed at the starting point, could read either a maximum of a (+) .001" or a maximum of a (-) .001" but not both in traversing the reference length of 24".

Another possibility is a reading showing a maximum rise to a (+) .0002" decreasing to a maximum of a (-) .0008" thus making a total reading not exceeding the permissible error of .001".

Sec. 23.14
Unilateral Tolerance

A unilateral tolerance is one wherein the allowable error is required to be on a designated side of a zero-zero reading. It further means that the reading may vary from zero to the maximum while proceeding the allotted reference length in the specified direction. For instance, Fig. 23.4 shows the tolerance allowed for the top of a Vertical Milling Machine table being square with the spindle. The recommended tolerance is 0 to .001" in 12" The direction of movement as well as the starting point is implied in the statement "low point in rear".

A DIAL INDICATOR is placed in contact at the front of the table and there zeroed. The swing round method is used to bring the contact point of the instrument from the front to rear through a 180° movement. It is permissible for the reading to decrease a maximum of minus (-) .001" in the reference length of 12", but

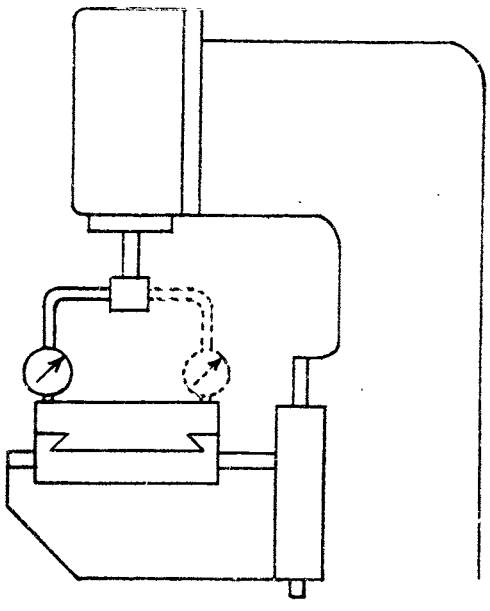


Fig. 23.4 Example of unilateral tolerance. (Side view) Vertical Milling Machine. Table top square with spindle (Front and Rear) Max. .001" in 12". Preferably low at rear.

the total deviation in the direction measured cannot exceed this amount.

For convenience' sake the test may start at either front or rear but the reading must be interpreted in light of the instruction "low point at rear."

SUMMARY:

The final working accuracy of an assembled machine is the result of a suitable utilization of all tolerances admitted in the manufacturing and/or reconditioning of the individual components, in the sub-assembly of the latter, and the final assembly of the part groups.

Bilateral tolerances of the individual surfaces and members must be equalized as a guarantee of the aggregate accuracy of the complete machine.

When all static alignment tests have been satisfied, the scraper is not responsible if the machine under normal usage does not perform as anticipated because of flimsy design.

Sec. 23.15
Amount of Tolerance

The value of the tolerance allotted a surface depends on the importance of the alignment concerned. It is axiomatic that the more important the part, or expressed another way, the more that part affects the accuracy of a certain operation, the greater is the specified precision.

Similarly, errors which may be allowable on one kind of machine may be inadmissible on another. For example, when parallelism is concerned, a deviation of 1/4 thousandths of an inch per foot would in many cases be acceptable for the bed ways of lathes. But for precision grinding machines parallelism in the bed ways is the paramount requirement. In these cases, a divergence of no more than .0005" can be permitted in the overall length of the bed.

This brings us to a question frequently asked. "Should the operator suspend scraping immediately after achieving the alignment modified by the tolerance?" The answer to this is "No, it is far safer to continue scraping until the alignment is bettered by an amount equal to one half (1/2) of the tolerance given." In short, the experienced operator will try to exceed the bare minimum requirements. Doing so provides a little leeway for slight inaccuracies in the gaging tools and minor errors in their manipulation. The extra time required for a few additional scraping cycles will not cause significant delay. On the other hand, it will enhance the accuracy of the machine.

To save time a surface is sometimes passed when it lacks the recommended degree of accuracy. Whether this is advisable or not is necessarily left to the judgment of the individual operator who should be influenced by the Alignment Test Record Cards. Such a course may be permissible if the type of work to be produced by a machine is not of a critical nature. But if the job requires strict limits of tolerance or precision, then the most exacting tests must be performed conscientiously and repeatedly.

A deficient alignment is remedial if the situation of the bearing surfaces permits the utilization of bi-lateral tolerances. In such a case it is only necessary to equalize the error on one surface by arranging an equivalent error on the next surface but in an opposite direction. In short, a plus tolerance is assigned to cancel a minus one. Thus errors in individual components, if balanced against each other, will have a negligible effect upon the working

accuracy of the machine as a whole. Effectual utilization of bi-lateral tolerances should be routine practice on all surfaces where this is feasible to avoid Cumulative Error.

Sec. 23.16
Cumulative Error

A cumulative error is one whose degree or significance gradually increases in the course of scraping a series of bearing surfaces. More specifically, it is one that is repeated on a related sequence of machine members, becoming larger by successive additions.

This condition is liable to develop in the process of scraping sub-assemblies of machine tools. The origin of Cumulative Error may be traced to the superficial assumption that when scraping operations conform to the tolerances allotted each individual surface, the eventual result will be a correct alignment of the machine as a whole. This does not necessarily hold true if the various sub-assemblies were not checked, surface by surface, against the common Datum Point.

To prevent this development it is additionally imperative that the assigned tolerances be so oriented that the misalignment of successive members balance off the misalignment of preceding members. In other words, by equalizing bi-lateral tolerances, cumulative error is avoided. This practice insures that the final alignment will be within the permissible aggregate accuracy of the completed machine.

The experienced scraper does not strive for perfection of alignment on the members of a particular machine being treated. Such a procedure would be uneconomical because it would squander time needlessly. Consequently, tolerances are permitted.

The skilled scraper by knowing the alignment tolerances allowed in the final static tests of a machine can allocate scraping tolerances to each machine member, or sub-assembly, to the end that the final alignment tolerances are not exceeded. By this means he expedites the work and achieves a satisfactory degree of accuracy in the completed machine. Through the proper manipulation of permissible bi-lateral tolerances, a cumulative error can be by-passed. In short, it is feasible to cancel off a plus error occuring on one surface by assigning a minus error of equal proportions to a surface of another member.

Since cumulative error is a never-ending problem in alignments, it might be advisable to discuss it more fully. While it affects all types of machine tools, it is a factor of major importance on milling machines, especially those having a universal saddle. On this class of machine the members are, to use an expression "Stacked like a layer cake". (See Fig. 27.75a) When individual components of a particular machine are mounted on top of the other in this fashion, the top-most one, comprising the working surface, must be aligned to the Datum Point within a certain tolerance so that the machine will produce accurate work.

As an example of how cumulative error affects alignments, consider the case of the front-to-rear alignment of a milling machine table top. The working surface of the milling machine is the table top which is always assigned a unilateral tolerance "high in front". It can be achieved only through the prior and correct alignment of the ways of the knee. These are allotted the same unilateral tolerance as the table top. Consequently, both surfaces become a factor in cumulative error.

Other members, having a total of four bearing surfaces, intervene between the knee ways and the table. They also must be scraped to proper alignment but without altering the relationship intended for the above mentioned knee ways and table top. This is accomplished with a minimum of effort by utilizing the bi-lateral tolerance assigned to each surface.

The first member which could affect this relationship is the saddle, which has two groups of bearing surfaces. The next member influencing cumulative error is the swivel block, also with two groupings of bearing surfaces. The scraping tolerance on these four sets of bearings is determined by whatever over-all accuracy the machine tool is to have. Accordingly, the operator is obliged to arrange the scraping tolerance on the ways and slides so that a possible plus error on one level will be equalized or opposed by an equivalent minus error on another level. Thus they will cancel out.

An equal, bi-lateral tolerance is allowed for each surface (except the knee

ways and table top which as we have stated before, have a unilateral tolerance, and the table slides which are always scraped parallel with the table top) but the final dimensions of the bearings must be within the permissible aggregate accuracy of the complete machine. This is possible only if the location of the error is alternated, first to the front, then to the rear and so forth, with successive members.

To summarize, Cumulative Error can be avoided if the following precautions are observed; viz:

First, the operator should not exceed the tolerance allotted each individual surface. Second, he must alternate the direction of bi-lateral tolerances utilized on successive surfaces. Finally, he must not exceed the tolerance allotted to the machine as a whole, i.e., the tolerance permitted for the working surface.

There is yet another aspect of Cumulative Error peculiar to milling machines, namely Offset of Pivot Axis of Universal Saddle, which is discussed in Sec. 27.75. This concerns the displacement of members from their original relationship to the pivot in the horizontal plane. Since it comes about as a natural result of removing metal it is unavoidable, though certain remedial measures can be taken, as will be explained.

Sec. 23.17
Testing for Cumulative Error between Top of Table and Flat ways of Knee.

Fig. 23.5 shows a practical test for Cumulative Error and illustrates the points discussed in the preceding section. It can be applied to all types of milling machines. Briefly, the set up is as follows:

The saddle is traversed inward

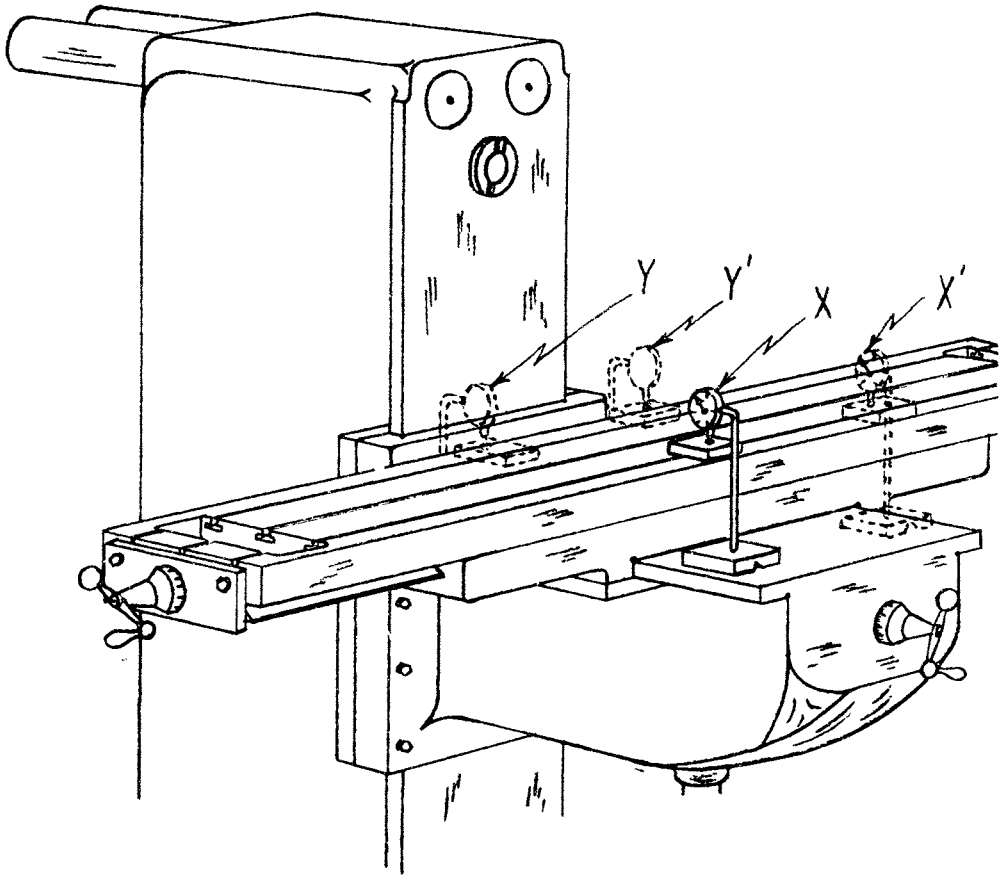


Fig. 23.5 Testing horizontal milling machine for Cumulative Error. (Flat way of knee to top of table) Tol. .00025". High in front.

sufficiently to provide room on the flat way of the knee for a Surface Gage and attached DIAL INDICATOR. After placing the button of the instrument in contact with a ground block, as shown at (X) in Fig. 23.5, a reading is taken. The apparatus is moved next to (X') where another reading is noted. The saddle should now be traversed outward to make room for the INDICATOR stand at the other side. Additional readings are now taken from the opposite side at positions (Y-Y').

An identical reading at all four points is desirable, but the difference should not be greater than .00025", high in front. Should the tolerance be exceeded, then each member of the sub-assembly must be tested individually for parallelism. In other words, all the saddle and table surfaces are re-checked.

If the scraper properly utilized the bilateral tolerances in fitting together the several components comprising the subassembly, and further provided that the unilateral tolerance accorded the flat ways of the knee was not exceeded, then the table top, which is the plane from which the final static tests are made, will be within the tolerance demanded of the complete assembly.

Sec. 23.18
Working Pressure

Working pressure is a term used to describe the stresses and deformations induced in a machine tool when the driving motive power forces the work piece into the cutting tool, or brings the cutter to bear against the piece of work, as the case might be. As a result of this pressure, which causes intermittent, variable or continuous strain, there is a tendency for one or more members of the machine to twist out of alignment with adjacent members. Working pressure then is a factor which tends to impair the alignment of machine members under actual working conditions.

Machines of modern construction have parts greatly strengthened both as to ruggedness and rigidity to withstand, in so far as possible, distortion in the individual members which would be detrimental to the accuracy of the output. Although machine design has been improved, there has been also an accompanying increase in driving motive power. This permits heavier cuts to be made on harder metals at faster speeds. Needless to add, this development has not minimized the problem of maintaining accurate work size.

When the various members of a machine tool are subjected to working pressure, the alignment of one member with another is altered. For this reason both new and used machines are scraped so as to allow for this factor. In other words, certain surfaces of a machine are permitted a slight misalignment under static, or non-operating conditions. This permissive error is called a unilateral tolerance and must always be in one direction. It must always oppose the deformation expected, which is the working pressure. Thus under normal operating conditions, these surfaces approach perfect, or near perfect alignment, due to the effect of Working Pressure. We see, therefore, that while this force has its bad effects, it may be neutralized if correctly estimated and appropriate steps taken.

It is very difficult to estimate for Working Pressure with absolute accuracy because the conditions under which a machine operates are so variable. The rate of travel, the width and depth of cut, the kind of material, all vary from job to job. The builder of the machine is perhaps in the best position to know the tolerances which can safely be applied. As each new model of a machine tool is developed, it is thoroughly investigated by the manufacturer. Tolerances are assigned to each member on the basis of this study.

With a machine used for manufacturing purposes, where only one type of product is produced under fairly constant operating conditions, it is possible to closely approximate the value of the working pressures. It is a different matter, however, with the tools found in a machine shop. Here the variety and range of jobs performed on a single machine is so extensive that only an average value can be assigned to Working Pressure.

To scrape a machine for either set of circumstances, the operator should be guided by the recommendations given in the Manufacturer's Test Record Cards. Lacking these, a good rule of thumb is to allow a unilateral tolerance for a member under stress of between .001" and .0015" per 18" of length of movement in a direction opposing the working pressure. For

a finishing cut this allowance may not provide all the accuracy desired, and on the other hand, for a roughing cut it might be unnecessarily strict. But until adequate information is available about the particular assignment of the machine, it will represent a fair compromise. Obviously, to apply this formula most effectively, the scraper must be thoroughly conversant with the cycling of the machine. That is to say, he must be qualified by training and experience to make correct decisions as to which members require a unilateral tolerance and which members can be satisfied with a bi-lateral tolerance.

Sec. 23.19
Effect of Working Pressure on Alignment Tolerances

Working pressure, which causes a deformation in the machine tool, influences alignment tolerances both as to direction and degree. For example, in the case of a horizontal milling machine (Fig. 23.5) the work table is permitted a tolerance in a direction parallel with the spindle and rising at the front. The table must never slope down at the front.

The reason for this requirement can be seen by studying the machine under actual working conditions. As the cut is started, the front of the table tends to sink downward under the pressure of the tool while the arbor supported by the over arm bends upward. The effect of the unilateral tolerance is to counteract to a certain extent the distortion caused by working pressure.

Every type and model of machine tool is tested by the manufacturer under a variety of conditions. Permissible tolerances are carefully calculated and are based upon the degree of deflection noted. Consequently, the scraping operator when reconditioning a machine should rely on the recommendations incorporated in the Manufacturer's Alignment Test Record Cards.

Sec. 23.20
Preserving the Original Plane

The term "Preserving the original plane" means that, in the process of reconditioning a bearing surface, it will be scraped flat and to a good quality without altering its original relationship or alignment with other surfaces and parts established during manufacture. In all cases when rescraping a machine, the goal of the scraping effort should be to produce a new bearing surface that has this characteristic. Although this objective is spoken of generally as in the title above, it would be technically more correct to say "Producing a surface parallel with the plane of the factory-new surface." It is shortened for the sake of brevity.

The problem of preserving the original plane of a surface, which is closely related to finding the correct Datum Point of the machine, is important for the following reasons, viz:

1. To reduce the amount of scraping work on other surfaces that bear against the surface in question.
2. To eliminate the need for excessive or radical re-arrangement of gears, shafting, feed screws, radial bearings, etc. necessitated by a realignment of the scrape-finished flat bearing surfaces tangent to the original or factory-new plane.

To show how the Datum Point will aid in preserving the original plane, let us consider as an example the rescraping of the column face of a horizontal milling machine shown diagrammatically in Fig. 23.6. In this case, the logical Datum Point

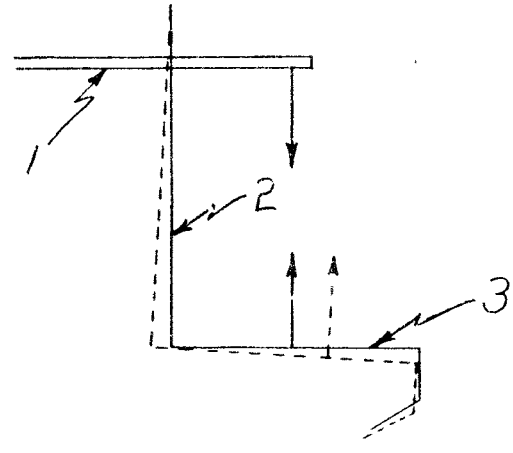


Fig. 23.6 Diagram showing effect on alighments of horizontal milling machine of disregarding Datum Point. Solid lines represent correct alignment of original surfaces. Dotted lines represent rescraped surfaces.

(1) Spindle (2) Face of column (3) Knee

is the axis of rotation of the spindle, and the column face should be scraped square with it. This must be done regardless of the surface condition of the column face. As a rule, the upper portion of the face will have deteriorated very little, if at all. Under normal conditions the heaviest wear will have taken place on the middle and lower parts of the column. Thus to ignore the original plane and just scrape the column face flat would be essentially to tilt the surface in-ward at the bottom. Although the result would be a flat surface it would not be square with the axis of rotation of the spindle, hence the alignment would not be acceptable.

The correct procedure is to remove the thickest layer of metal from the top portion of the column face even though no perceptible abrasion occurred there. A thinner layer is scraped from the middle and lower sections where the wear was greater. By using the spindle of the horizontal milling machine as the Datum Point, first the column face and then the surfaces of other members of the machine are scraped to a good bearing meanwhile preserving their original plane. In this case it is virtually impossible to produce a surface in a plane other than parallel to the original factory surface because the Datum Point is immovable.

A more striking example demonstrating the necessity of preserving the original plane of a surface is presented by the scraping procedure on a vertical milling machine. On this type of machine the spindle in its housing has a vertical adjustment and is subject to the misalignment of its flat bearings. Therefore, it is preferable to employ the face of the column as the Datum Point for all the other surfaces. An examination of the column face will invariably show that the middle and lower portions receive heavier wear. It will also be seen that deterioration is scarcely evident on the upper part.

The natural tendency of an inexperienced operator in these circumstances is to scrape the column face to a flat bearing surface by removing the minimum amount of metal. If this were done the face would tilt in-ward at the bottom. And since the knee must be scraped to align with the column, this in turn would require a radical shift of the head to correctly align the spindle. Fig. 23.7 will make this clear.

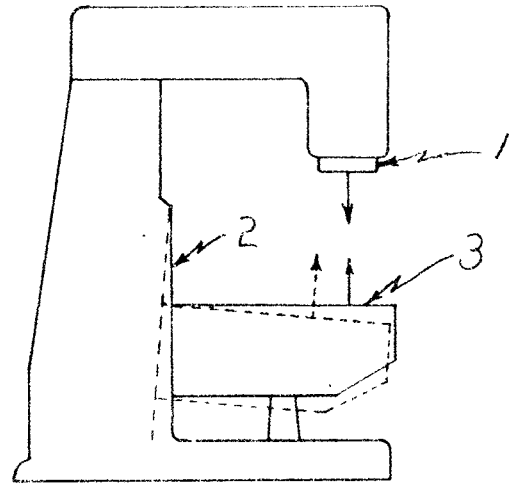


Fig. 23.7 Diagram showing effect on alignments of Vertical Milling Machine of disregarding admonition to "Preserve original plane." Notice the unnecessary work required to align spindle to new relationship. Solid lines represent original plane of members. Dotted line denote re-scraped surfaces

(1) Spindle (2) Face of column (3) Knee

Very probably there might also be an inclination sidewards one way or the other on the column face, thereby requiring further modification of the affected members. The significance of this change can be seen in Fig. 23.8. The solid line (A-B) represents the original factory-new surface, and the dotted line (a-b) denotes the plane of the newly scraped column face. Notice that the face shown by the dotted line was not scraped so as to parallel its original plane. One side of the face, apparently because it was more worn, or for another reason known only to the mechanic, was scraped more heavily and lowered to the line (a-b)

The results of this "time saving plan" are most unsatisfactory because under the new conditions the surfaces of the knee will no longer match the original alignments as closely as they should. The guided slide (D), for example, must be scraped to the line of (d) and the total replacement of the gib (G) by a larger piece may be called for. And this is not all.

Due to the extreme shift which the knee undergoes following the excessive removal of metal, any gearing or shafting dependent on the original alignment of this member or of mateing members, is also affected. It may be a costly operation to

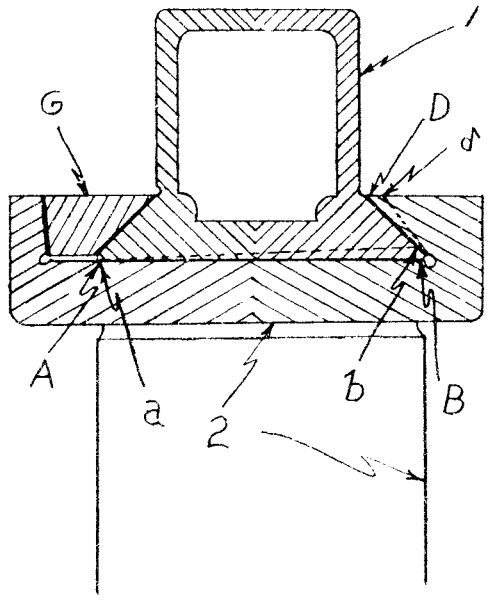


Fig. 23.8 Cross-sectional top view of Vertical Milling Machine showing adverse cumulative effect on knee member by failure to preserve the original factory plane of column face.

(1) Column (2) Knee

machine these elements or adjust them to a new position and thus restore their original alignment. Finally, the alteration of all gears, shafting and radial bearings situated in the head and coupled to the column, will be required to compensate for tilting the column face.

The plan proposed for preserving the original plane, and thereby largely eliminating these difficulties, is to scrape the surface "straight down."

Sec. 23.21
Scraping Straight Down.

If it can be said that there is one maxim in the reconditioning of machine tools more important than any other, it is the admonition to "Scrape straight down." This term describes a process for removing the metal from a worn surface in such a way that the final result is a new bearing parallel to the plane of the original (factory-new) surface. Though applicable to all components it accomplishes the most far reaching effects when it is brought to bear on the principal member.

On surfaces such as the face of a horizontal milling machine, where the spindle serves as a Datum Point, no conscious effort is needed to "scrape straight down" because obtaining correct alignment automatically produces an equivalent result. On the other hand, when no similar check point is available, a deliberate attempt must be made to apply this rule. Consequently, to avoid displacing gearing and shafts etc. more than is necessary, and to avoid extra work in aligning the bearing surfaces of other associated members, the operator must purposely scrape "straight down". The precision of the operation is dependent solely on the ability of the individual mechanic. He must have a knack with his hand scraper tool co-ordinated with a good judgment of the required pressure to be applied to the scraping stroke. Since these faculties are sharpened by practice, skill will come only with experience.

The first step in scraping "straight down" is a thorough examination of the surface, to locate, if possible, traces of the original factory surface. Decorative frostings or scraper tool marks are the clues hunted. If the surface is too badly worn, and they cannot be found, there is a possibility that adjacent surfaces may provide some useful information. Knowing what type of service the machine had performed, or the kind of product turned out, would also be helpful. For instance, a manufacturing process involving a repititious movement of but one member would suggest that other members may still largely retain their original factory plane.

When all possible clues are gathered, the next step, the reduction of the surface by 1 to 3 thousandths of an inch to a plane parallel to the original factory plane, is comparatively easy. Naturally, as the thickness of metal to be removed increases, the possibility of committing error also increases. Similarly, the chance of blundering is more likely on a large surface than a small one.

In spite of these drawbacks, however, scraping a surface "straight down" is not in any sense a mechanical feat. All that is called for is a heavier penetration on those parts of the bearing surfaces which appear least worn. On succeeding cycles these areas should also receive deeper cutting than adjacent areas until in the judgment of the operator they are

equalized with the remainder.

This requirement should not be too difficult to satisfy. If there are any impediments to its execution they are, we believe, chiefly psychological. That is to say, it seems contradictory to scrape more heavily, a portion of a surface that appears to be in better condition than adjoining areas which are obviously worn. But regardless of how the bearing surface appears, or what the markings from a spotting cycle seem to indicate, this must be done. Otherwise, shafting, gearing, feed screws etc., associated with these members will be unnecessarily thrown out of line. Should this occur, considerable effort may be called for to rectify the situation.

Without resorting to specific examples at this point, it should be obvious that excessive misalignment of the auxiliary components could be avoided by scraping the flat bearings "straight down" and removing the proper proportion of metal from each sector of the surface. This restores the original relationship between the flat surfaces and the gears etc. If this rule is successfully practiced, they can be re-inserted with only minor adjustments since the normal wear on these parts usually keeps pace with the slight lowering or shift in position of all bearing surfaces due to scraping.

On the other hand, if no consideration is given to the application of this important rule, it may necessitate extensive rebuilding, to compensate for improper scraping procedure. Needless to say, this can be an expensive and time consuming operation if the original accuracy is to be restored to the machine.

If the advice to scrape "straight down" is disregarded, the operator can show speed at the start of a job. However, the time saved on the first member is lost several times over when treating other components which have a definite relationship to the first. Finishing a surface in the shortest time is to be recommended whenever possible, but if this merely means removing the smallest amount of metal to produce a good bearing, without regard to other factors, the effort defeats itself in the long run.

By failing to produce a surface parallel to the original factory-new plane, at least as much metal must be scraped from another surface of the same member, or even from a second member, to effect proper alignment. In the final reckoning, there is no net saving of time in this phase of the work, and as we have explained above, the effect on the alignment of auxiliary parts is damaging in the extreme.

Fig. 23.9 shows diagrammatically what is meant by the expression "Scraping straight down." This subject is considered in greater detail in the following section.

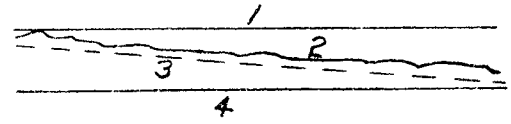


Fig. 23.9 Diagrammatic representation of the principle of "Scraping Straight Down."

(1) Original factory-new surface.

(2) Contour of the worn surface to be rescraped.

(3) An improperly scraped surface wherein the minimum amount of metal was removed in order to obtain flatness and good bearing quality. It is not parallel to plane of the original factory-new surface.

(4) A properly scraped surface that has the three essential characteristics

(a) Flatness (b) Adequate bearing quality (c) Parallel to the plane of the original factory-new surface

Sec. 23.22
Displacement of Dependent Gears due to Scraping

It would not be accurate to leave with the reader the impression that strict application of the principle of scraping "straight down" and preservation of the original plane obviates all necessity to realign gears, shafting, radial bearings etc. Actually, all scraping on flat bearings directly affects dependent gearing, and a member will change position in direct proportion to the amount of metal removed from the surfaces. For this reason depth of penetration should be kept to the very minimum and, in so far as possible, a plane parallel with the original factory-new surface ought to be reproduced.

Much of the difficulty in adjusting the small parts to the new situation can be eliminated if sufficient attention is paid to rescraping the various bearing surfaces

parallel to the original factory plane. This helps to maintain the mutual relationship which was established at the time of manufacture. However, in spite of this precaution, the auxiliary components will be offset and binding will occur if too much metal is removed from the flat bearings. When surfaces are very heavily worn this, of course, may be unavoidable.

If the displacement of the surfaces is not large, the gearing may accomodate itself to the altered conditions without readjustment. In other cases where scraping was heavy, extensive rebuilding is obligatory. Failing to scrape "straight down" simply aggravates the difficulty.

To demonstrate the effect on gears assume, for example, that the scraping job represented in Fig. 23.10 is involved. If

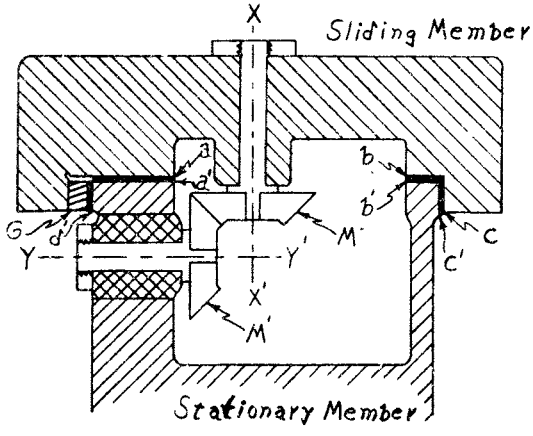


Fig. 23.10 Cross-sectional view showing displacement of gearing due to removal of metal from flat bearing surfaces.

the surfaces identified by the heavy black areas and designated on the sliding member as (a), (b), (c) and on the stationary member as (a'), (b') and (c') are scraped, the effect is to shift the upper member to the left, as we view the drawing, and also to lower it. This, obviously, would cause the miter gear (M) to crowd the gear (M') and they would be too tightly meshed to revolve. A simple machining operation to face off the backs of the gears, or the collar on their shafts, would restore the desired degree of back lash, provided the surfaces were scraped parallel to the original factory plane. However, in case the surfaces (a), (b) and (c) or (a'), (b') and (c') were tilted by failure to scrape "straight down", the center angle of the gears will be altered and they will not mesh properly as the two axes (x-x') and (y-y') would not be at a right angle. Gib (G) must be increased in size by the amount (d') in all cases.

Thus we see that auxiliary components can accomodate themselves to a slight change in position of a surface. If scraping were heavy, as in the example just cited, a simple machining job may well restore the gears to smooth operation. But if the newly scraped surface is not made parallel to the original factory plane, major rebuilding will be mandatory.

Sec. 23.23
Precedence in Alignments

To resolve any questions in the reader's mind it can be stated categorically that the alignment of the flat bearing surfaces takes priority over the positioning of gearing, shafting, radial bearings, feed nuts and screws etc. Scraping the flat bearings to a good finish and correct alignment is the fundamental operation and the auxiliary components are shifted to accomodate the changed circumstances. It cannot be otherwise.

Sec. 23.24
OBJECTIVES

An OBJECTIVE, as the term is used throughout this book, refers to certain conditions which the operator undertakes to bring about, in order to improve the bearing quality of a surface or align it. This expression means the attainment of specified physical qualifications which in aggregate produce a well nigh perfect machine. In short, it is the goal of the scraping effort.

The ends sought are the minimum essential requirements of a perfectly functioning machine. They are realized by pursuing a logical course of scraping operations, meanwhile observing all the rules which experience demonstrates is good practice.

Although this section will introduce OBJECTIVES to the reader in a general way, it is not until we discuss their application to the PROCEDURE of reconditioning representative bearing surfaces and machine tools, in the latter part of this

book, that the real significance of the term can be appreciated. At that time the OBJECTIVES, which are outlined in advance of the PROCEDURES, will point out the alignment or essential relationship of the surface concerned and the quality of bearing required. They are specifically worded to direct attention to a particular feature of a member or surface. However, while other members are excluded from immediate consideration, this is done merely for purposes of simplification. The experienced scraper always considers not only the surface he is presently working on, but also related surfaces. For this reason he will not confine his attention to one narrow and specific goal to the neglect of others.

For example, an OBJECTIVE specifying flatness in a surface may frequently be attained most easily by following the path of least resistance i.e. removing the minimum amount of metal. By doing this the goal, it is true, will be attained, but the results of failing to reproduce the surface parallel to its original plane are definitely unfavorable, as has been shown.

Operations on a given surface involving both alignments and the production of a good bearing should be planned so that all the OBJECTIVES designated are achieved simultaneously. In other words, scraping operations should be so synchronized that an alignment is not attained before the surface has been given an adequate bearing quality and vice versa.

Sec. 23.25
Simultaneous Achievement of Bearing Quality

Adequate bearing quality is one of the essential OBJECTIVES of all scraping operations. However, it cannot be obtained independently of the other OBJECTIVES. Generating adequate bearing quality and achieving accurate alignment go hand-in-hand. From the very start of the job the scraper should co-ordinate his efforts to accomplish this dual result. Thus on surfaces having poor alignment, efficiency demands deep cutting for the initial cycles. As the alignment is progressively corrected the depth of cut should be correspondingly reduced leading to a betterment in the bearing quality.

During the finishing stages on a piece of work, the operator should so conduct the scraping that at the end of each cycle, the existent bearing quality satisfies all requirements i.e. the required number of bearing spots per square inch, uniformly distributed. Then, if the final static tests prove that the alignments are correct, the job is done. In other words, when the correct alignment is attained it should not be necessary to resume scraping in order to produce the necessary bearing quality. It is of no value to achieve an acceptable alignment while the bearing quality is still inadequate. The alignment may be destroyed following the first light scraping conducted to improve the bearing quality. The operator thus loses his hard won ground and finds himself right back where he started. The only logical course is to achieve all OBJECTIVES simultaneously.

In striving to avoid the mistake mentioned above, the operator should not fall into the opposite error, namely, developing a good bearing quality prematurely. The absurdity of such a procedure is evident even to the novice yet the habit is surprisingly common. It is objectionable principally because it slows the work unreasonably.

Sec. 23.26
The Case for Reconditioning
(Manufacturing vs. Reconditioning)

The time allowed in a factory for scraping a particular piece of work may be far less than the period required to rescrape the same piece of work after it has deteriorated from wear. A comparison between factory operations and conditions as they are usually found in the average machine shop, or maintenance department, will illustrate this. Among the more important factors responsible for this difference are the following:

1. (a) Work reaches the factory scraper hand in a flat, straight condition. The thickness of metal to be removed will be approximately .003". From experience it is known that this allowance is adequate to accomplish the desired alignment and produce the requisite bearing quality, thereby reducing hand scraping to a minimum.
   (b) In contrast, the maintenance man

may find, following an inspection of the work piece, that a thickness of .015", or more, depending on the amount of wear, must be removed. Furthermore, he frequently discovers that the surface, far from being flat, has instead degenerated into a pronounced convexity.

2. (a) The factory scraper always has available an accurate spotting template for each bearing surface.
   (b) The maintenance man, on the other hand, must continually improvise from his small stock of standard spotting tools and must often construct his own.
3. (a) The factory scraper-hand works under ideal conditions where he usually is able to direct the scraping stroke to the surface from all angles.
   (b) Frequently, the construction machinist must perform similar operations under the most trying and awkward conditions. Many times the surface needing treatment must be scraped while still fitted in place on a machine. To dismantle the machine and free the part, might involve considerable work.
4. (a) The factory operator has gaging instruments, specially designed, or adapted for his use, to check parallelism, alignments etc.
   (b) The reconditioning expert doing much of his work under stringent limitations of time and facilities finds it necessary to adopt many practices not essential in factory production. At the same time he must meet the same exacting standards of accuracy.

The several points summarized above are but a few of the reasons, why a particular machine component frequently costs considerably less to manufacture than to recondition. On the other hand, balanced against this is the lost production if the machine must be returned to the factory for repair. On a general overhaul many other factors enter the picture which are beyond the scope of this book.

Sec. 23.27
Test Record Cards

Satisfactory performance of the modern high-precision machine tool of today requires precision equipment in order to restore the machine to the original condition it operated when new. In conjunction with this testing equipment, the manufacturer's specifications should be adhered to when making all necessary adjustments in order to obtain accurate work output and satisfactory finish. These specifications will be found incorporated in the Manufacturer's Test Record Card. The operator uses these Cards not only to identify the parts needing alignment, but also to ascertain the permissible tolerance.

Alignments are achieved by scraping the bearing surfaces until they are flat and have a good bearing quality and are in proper relationship to a suitable Datum Point or Datum Plane. Since it is impossible to tell exactly how much is being scraped off in each cycle, although experienced operators can judge within close limits, the work necessarily is a cut and try procedure. In other words, removal of metal must be alternated by appropriate and meaningful tests.

Test Record Cards are extremely helpful on four counts, enumerated as follows:

1. If a systematic and periodic check-up of operating machine tools is in force in factory or shop, the cards, by furnishing standards of tolerance, will give an indication of the extent of wear present. The need for minor repairs, which if neglected could lead to a major overhaul and the long "down time" consequent to this operation, can thus often be anticipated.
2. An analysis of the test card will ordinarily reveal the allowable alignment tolerance which can be permitted during the rescraping of the several subassemblies.
3. The final static and working tests, provided they conform to the Manufacturer's Test Record Cards, will assure an adequate performance of the reconditioned machine when placed in service.
4. The test card, in addition to giving information on tolerances, procedures etc., usually provides a check list of

auxiliary parts which require adjustment etc. This part of the test card is of special interest to the mechanics who assemble the machine and give it regular maintenance inspection.

NOTE: Manufacturer's Test Record Cards are not to be confused with the operator's instruction manual which usually accompanies the machine tool. These cards are supplied by the manufacturer upon request and should be available to the scraper prior to the start of any rescraping job.

Sec. 23.28
The Test Card Explained

Test cards comprise an aggregation of diagrams, with accompanying tolerances, instructions etc., each of which represents a test which must be satisfactorily performed before the machine being tested is accepted.

Since the scraping operator will have many occasions to consult alignment test cards, it is advisable for the novice to thoroughly familiarize himself with the contours representing the various machines, the symbols and the instructions accompanying each diagram. Although the number of variations runs into many hundreds, it is impossible to discuss in this chapter more than a few typical examples. However, once the fundamentals are understood, it is a relatively easy matter to interpret the diagrams and apply the test.

Two classes of tests are incorporated in the Test Record Cards.

1. Static tests. These are made on subassemblies and on the completed machine without using power.
2. Working tests. As the term implies these have to do with the performance of the machine in various machining operations.

In the following paragraphs, as well as in the legends associated with the figures, the various features that make up test cards generally will be explained.

1. The most prominent feature on the test card is the diagram. As the examples in Fig. 23.11 show, it is drawn in simple form so as to illustrate in the clearest manner the kind of machine or member being tested. Consequently, the drawings contain a minimum of detail. Sometimes only a portion of the tool is outlined. Components not essential to comprehension are excluded. The point of view is usually stated. Incidentally, test cards issued by different factories will be found to vary in some small degree in the representation given to similar categories of machines and parts.
2. The tools and gages shown on test cards are not drawn to a perfect likeness, either as to type of form, or even as to scale. See Fig. 23.12. Furthermore, the placement of a tool or gage, or the method of clamping it, is not functionally authentic. In other words, these diagrams are merely figurative. The movement of the tool or gage or member being tested is often indicated by dotted lines denoting one of the two extreme positions to be occupied. Where the positioning of the gage could lead to confusion as to the particular part of a member to be tested, a printed explanation is always included.
3. Procedures must be significant to provide the information desired when proving the accuracy of an alignment. Fig. 23.13 shows how this is assured by means of arrows indicating the direction of movement of the testing gage, the member to which it is fastened or the component being tested. This practice is usually supplemented by printed instructions so no mistake can be made. Often where the test must be made in both the vertical and horizontal planes, this requirement is represented by drawing two gages either on or adjacent to the diagram.
4. An important feature represented on test cards is the test of components other than sliding bearings. These are allowed a maximum tolerance without reference to distance. See Fig. 23.14.
5. These cards also illustrate tests by means of which one surface is checked for parallelism with or squareness to another surface, as the case might be, with maximum tolerance allowed in a specified distance. Essentially, this category constitutes bi-lateral tolerances. See Fig. 23.15.
6. Test record cards include many ex-

amples of unilateral tolerances. Common to all of these is a maximum allowed error for a designated distance with the minimum reading or maximum reading always in a specified direction. See Fig. 23.16.

7. Test cards frequently include diagrams showing that the test is conducted within a specified length or that the testing instrument is set to take measurements at specified positions. See Fig. 23.17.
8. Test cards frequently contain one or more working tests for a machine. These are useful as a standard to judge the accuracy of the machine tool as it cuts and shapes metal. Representative tests are incorporated in Fig. 23.18.

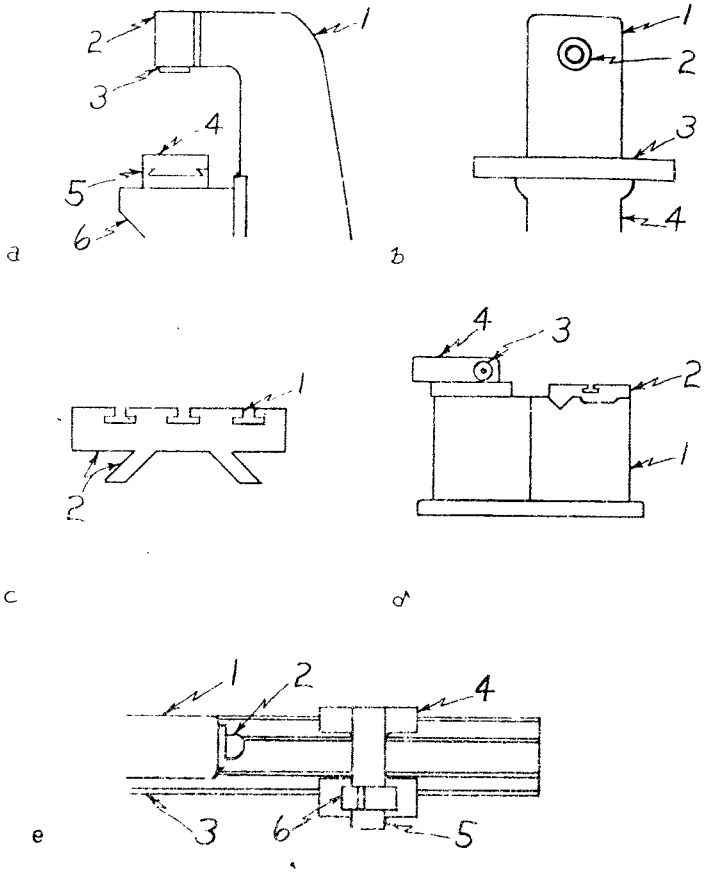


Fig. 23.11 (a) Vertical Milling Machine (Side View)

(1) Column (2) Sliding head (3) Spindle (4) Table (5) Saddle (6) Knee

(b) Horizontal Milling Machine (Front View)

(1) Column (2) Spindle (3) Table (4) Saddle and knee combined

(c) Milling Machine Table (End View)

(1) T-slots (2) Slides

(d) Cylindrical Grinder (End View)

(1) Bed (2) Table (3) Wheel spindle (4) Wheel head

(e) Lathe (Top View)

(1) Head stock (2) Spindle (3) Bed (4) Saddle (5) Cross slide (6) Compound rest

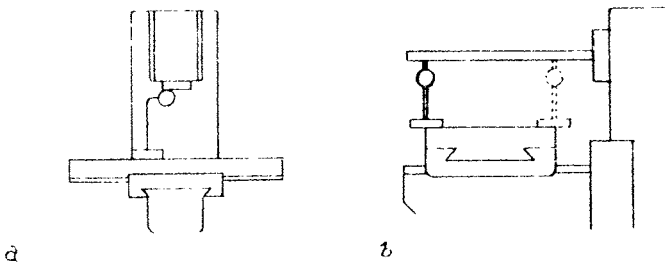


Fig. 23.12(a) Vertical Milling Machine, Spindle End Run out (Front View).

Registering cam action in spindle or bearings. DIAL INDICATOR is mounted on a substantial base or otherwise securely fastened to the table top. The button of the instrument is positioned to touch end of spindle. Deviation of the pointer is noted as the spindle is revolved.

Fig. 23.12(b) Horizontal Milling Machine, Table Top Parallel with Spindle (Side View).

Determining alignment of table top with spindle. DIAL INDICATOR measures from the front side of table top to the test bar inserted in spindle. A comparative measurement is then conducted by sliding the instrument represented by dotted lines to the back side of table top.

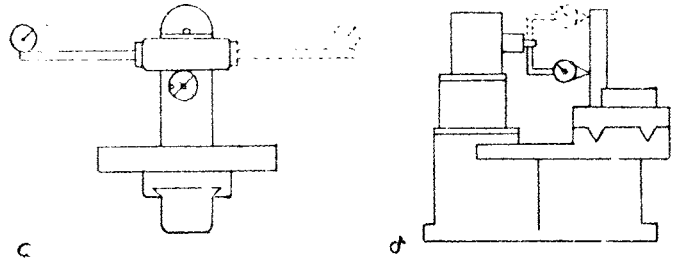


Fig. 23.12(c) Swivel Head Vertical Milling Machine, Line Up of Head Parallel to Top of Table (Front View).

Determining the accuracy of the graduations on a swivel head. The simple circle signifies that a DIAL INDICATOR is to be the measuring instrument. This gage will logically be mounted on a suitable base set on the table and moved as required. The button is adjusted to touch the vertical diameter of the test bar as the head is swiveled 90^{0} each side of zero (0). The variation in the readings as the plunger makes contact at the free end of the test bar in the two positions measures the accuracy of the graduations on the universal swivel head.

Fig. 23.12(d) Surface Grinder, Wheel Spindle Parallel with Table Top (End View).

Determining the parallelism between the wheel spindle and the work table. A square is mounted on the table top with the blade in-line with the axis of the spindle. A dial indicator is attached to the spindle by any suitable means, the extensions being made as long as possible to increase the accuracy of the test. The dotted outline denotes that the swing-round method is applied.

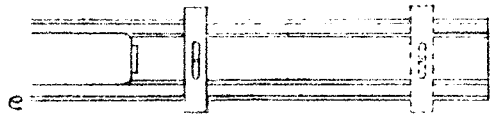


Fig. 23.12(e) Lathe, Bed Level - transverse direction (Top View).

Levelness check being made on a lathe bed in transverse direction. Though the precision level is shown only at the ends of the bed it is understood that checks are made at intermediate positions also. By comparing the readings taken at all points the degree and direction of twist is ascertained.

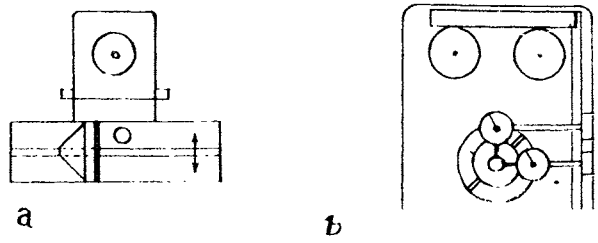


Fig. 23.13(a) Vertical Milling Machine, Center T-slot Square with Cross-Movement (Top View).

Determining that the center T-slot is square with the out and in movement of saddle. The test apparatus requires a gage adjusted square with the T-slot. This is represented by the figure on the table top. (A set up utilizing a Try Square is sometimes used or a special Angle Plate having tongues fitted to the T-slot can be substituted.) The circle represents a DIAL INDICATOR fastened to the spindle and brought into contact with the gage. The alignment is tested by moving the saddle-table assembly as indicated by the arrow.

Fig. 23.13(b) Horizontal Milling Machine, Parallelism of Overarms with Spindle in Vertical and Horizontal Planes (Front View).

Determining the parallelism of the overarms with respect to the axis of the spindle in two planes. A DIAL INDICATOR is attached to the overarm and so positioned that the plunger touches the test bar inserted in spindle at, say, the vertical diameter. The difference between the reading at the spindle end and the free end of the test bar as the overarm is cranked out and in, will indicate the misalignment.

To test the horizontal plane, reset the button of the instrument at horizontal diameter and repeat the movement.

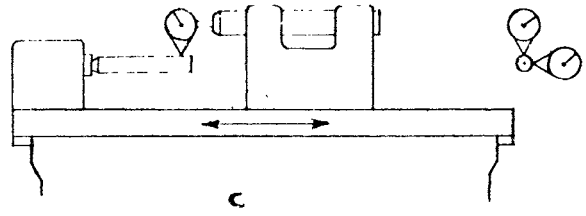


Fig. 23.13(c) Cylindrical Grinder, Axis of Headstock parallel to Table Movement (Front View).

Testing the bed ways and the axis of the work head for parallelism. That the alignment is to be tested in both planes is indicated by the insert. A precision test bar of appropriate dimensions is inserted in the spindle. The plunger of a DIAL INDICATOR attached to the wheel head is adjusted to to touch the test bar at, say, the vertical diameter. The instrument is actuated as the work table is moved as shown by the double headed arrow. The deviation in the DIAL reading between the headstock end and free end of the test bar is a measure of the misalighment between the axis of headstock and the table movement. (The horizontal plane is checked in like manner.)

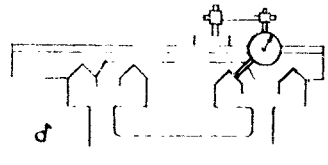
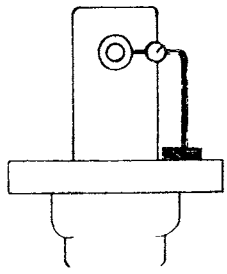


Fig. 23.13(d) Lathe, Tailstock Way Alignment (End View).

Determining that the inverted V-way guiding the tailstock is parallel with the outer ways of bed. To test this a DIAL INDICATOR fastened to the carriage is utilized. The plunger is touched to one side of the inverted V-way. Divergence from parallelism is noted as the carriage is moved from one end of bed to the other. Any variations in the readings represent the degree of misalignment. The other side of the inverted V-way is tested in the same fashion. Incidentally, no arrows are shown inasmuch as the direction of movement is obvious.



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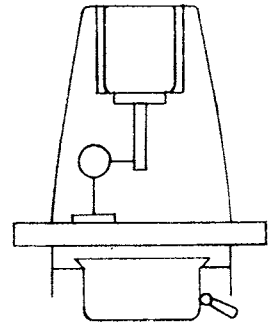


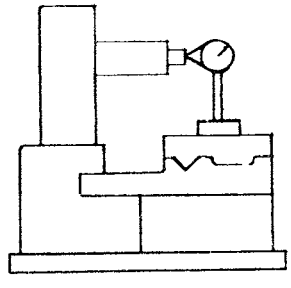
b

Fig. 23.14(a) Horizontal Milling Machine, Periphery Run Out - Max. .0002" (Front View).

Testing spindle of the horizontal mill for true running. A DIAL INDICATOR secured to a substantial base set on the table top has its plunger adjusted to touch the periphery of the spindle nose. The variation in the reading of the instrument as the spindle is rotated indicates the degree of periphery run out.

Fig. 23.14(b) Vertical Milling Machine, Movement of Knee when Clamp is locked - Max. .001" (Front View).

Measuring displacement of knee when clamp is locked. A movement of the knee, saddle, table assembly will occur when the clamp is tightened. Consequently, the correct placement of the DIAL to register this slack is very important. Adjustment should allow the plunger action of the instrument to parallel the direction of greatest movement. Tests are to be conducted parallel to face of column, as shown, and also square with the face of column. (Not shown)



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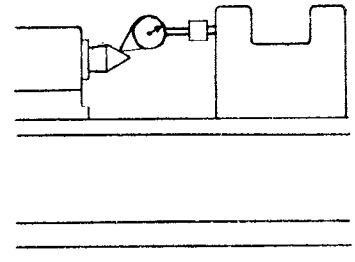


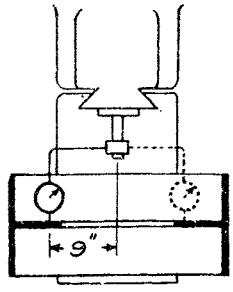
d

Fig. 23.14(c) Surface Grinder, Wheel Spindle for Axial Slip - Max. .0004" (Side View).

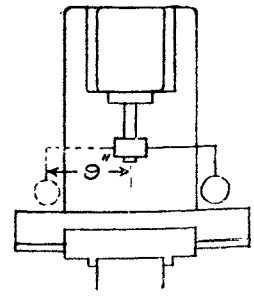
Testing wheel spindle for cam action. A DIAL INDICATOR mounted on a substantial base has its plunger adjusted to touch the wheel spindle at the axis. The deviation of the pointer, as the spindle is rotated, determines the degree of axial movement.

Fig. 23.14(d) Cylindrical Grinder Headstock Spindle, "Center Point for True Running" - Max. .0002" (Front View).

Determining whether axis of the work head center is concentric with the axis of revolution of the work head spindle. The DIAL INDICATOR is fastened to the wheel head, or may be positioned on the work table. The plunger is adjusted to touch the center, and the deviation of the pointer is noted as the work head spindle is revolved.



a



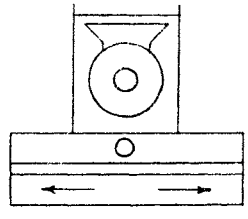
b

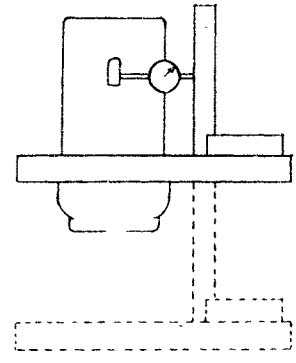
Fig. 23.15(a) Horizontal Milling Machine "Center T-slot Square with Spindle" - Max. .001" in 18" (Top View).

The dotted outline represents a swing-round test utilizing a DIAL INDICATOR fastened to the spindle. The button of the instrument is brought into contact with two parallel-sided steel plates inserted in the center T-slot of the table. Measurements are taken 18" apart after the table is centrally located.

Fig. 23.15(b) Vertical Milling Machine, "Table Top Square with Spindle" (Right and Left) - Max. .001" in 18" (Front View).

Testing alignment of table top with axis of spindle a swing-round movement of the DIAL INDICATOR is utilized to test 9" to the right and left of the spindle. To average out the irregularities a parallel sided test block is interposed between the button of the instrument and the table which should be centrally located.





c

Fig. 23.15(c) Vertical Milling Machine, Center T-slot Parallel with Table Movement - Max. .001" in 18" (Top View).

Testing center T-slot for parallelism with the slides of the table. The DIAL is attached to the spindle with its plunger adjusted to touch the throat of the T-slot. The double arrow indicates that the movement can be in either direction with the starting point at any position allowing an 18" movement.

Fig. 23.15(d) Horizontal Milling Machine, Table Top Square with Vertical Movement of Knee in a Plane Parallel with column - Max. .001" in 18" (Front View).

Determining the alignment of table top with the guiding way of column. A DIAL INDICATOR is attached to the spindle. A Master Square is positioned on the table top with the blade of the square in contact with the plunger of the INDICATOR. The dotted outline indicates that the knee, saddle, table assembly is raised and lowered. A misalignment will be indicated by a deviation of the pointer.

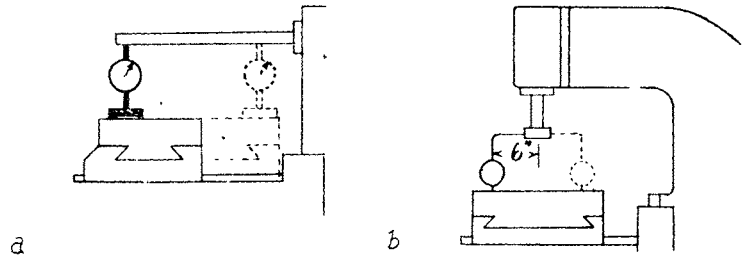


Fig. 23.16(a) Horizontal Milling Machine, Cross-Movement Parallel with Spindle (Vertical Plane) - Max. .001" in 12" - Low point at Rear (Side View).

Determining the alignment of the knee flat ways to the axis of the spindle in the vertical plane. The dotted outline indicates that the saddle-table assembly is moved inward carrying the DIAL INDICATOR to a new position under the test bar. Notice that the tolerance is restricted as to direction making it unilateral in character.

Fig. 23.16(b) Vertical Milling Machine, Table Top Square with Spindle (Front and Rear) - Max. .001" in 12" - "Preferably low in Rear" (Side View).

Determining alignment of table top to axis of spindle. The dotted outline denotes a swing-round movement testing the table top at two positions 6" apart. The unilateral nature of the tolerance is indicated by the qualifying phrase "low in rear."

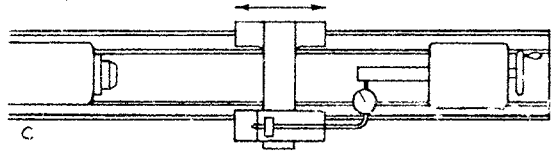


Fig. 23.16(c) Lathe, Tailstock Spindle Alignment - Horizontal Forward at End of Spindle when fully extended - 0" to .0005" (Top View).

Determining alignment of the axis of the tailstock spindle to the outer ways of bed. The test instrument is fastened to the carriage and the button is brought to bear against the spindle at the horizontal diameter. To actuate the instrument the carriage is traversed along the bed in another direction. (See double arrow) The distance traversed is not specified because it is obviously limited by the length of the extended spindle. The tolerance is unilateral as it is restricted by the requirement that end of spindle must be forward.

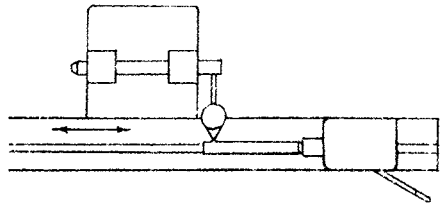


Fig. 23.16(d) Cylindrical Grinder - Footstock Ram Parallel with Table Movement in Horizontal Plane - Max. 0" to .0012" per 4" - "Front End inclined towards Grinding Wheel." (Top View).

Determining the alignment of the axis of the ram to the bed ways. That the tolerance is unilateral is denoted by the phrase "Forward end inclined towards grinding wheel." This means that with the DIAL INDICATOR registering zero (0) at the footstock end of the ram, the maximum plus (+) deviation is read at the free end of the ram.

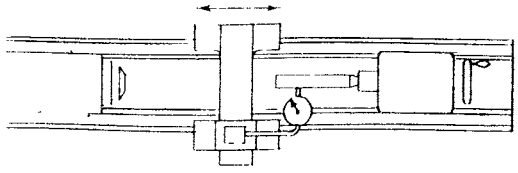


Fig. 23.17(a) Lathe, Tailstock Taper Alignment - Horizontal - Max. 0" to (±) .0005" - "End of 12" test bar" (Top View).

Example of a bilateral tolerance of the plus or minus type. This tests the alignment of the tapered hole in tailstock spindle to the outside ways of the bed in horizontal plane. Free end of 12" bar may not incline forward or backward in excess of .0005" with DIAL registering zero (0) at tailstock end.

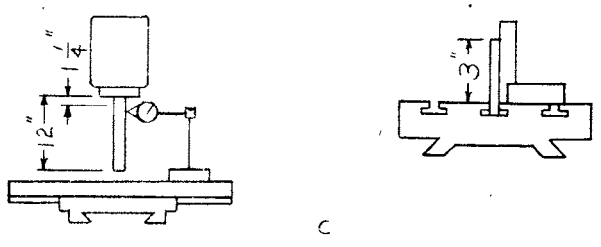


Fig. 23.17(b) Vertical Milling Machine, Spindle Run out. Max. 1 1/4" from end of spindle .0005"; Max. 12" from end of spindle .001" (Front View).

Detecting misalignment between the axis of rotation of the tapered hole in the spindle and the axis of revolution of the spindle proper. Run out tests are conducted on the 12" test bar at specified distances from the spindle nose. The allowable error increases towards the free end of the test bar.

Fig. 23.17(c) Table - Horizontal Milling Machine; T-slot square with Top of Table - Max. .001" in 3" (End View).

Checking alignment of throat of T-slot with top of table. The parallel sided plate inserted in the T-slot should extend at least 3" above surface so that the square may test with reasonable accuracy.

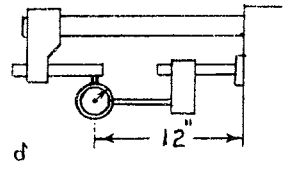
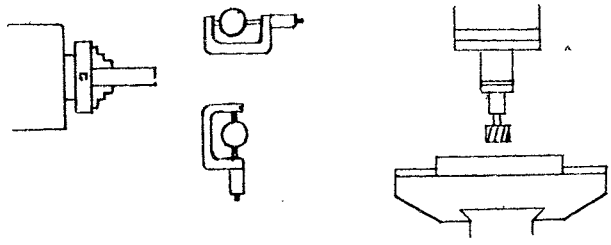


Fig. 23.17(d) Horizontal Milling Machine, Alignment of Arbor Supports with Spindle - Max. Run out .001" (Side View).

Determining the alignment between the axis of arbor support hole and axis of the spindle. That a swing-round movement is to be performed 12" from column face is denoted by the term "run-out."



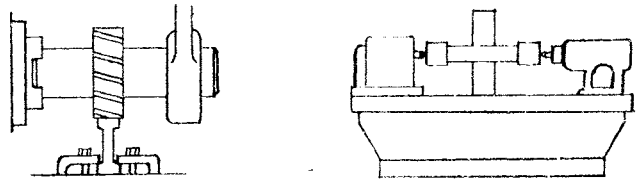
a b

Fig. 23.18(a) Tool Room Lathe.

Lathe must turn round with work mounted in chuck. Max. .0003" Tests spindle for true running. Measure diameter of bar for out of roundness with micrometer.

Fig. 23.18(b) Rotary Head Tool and Die Milling Machine.

Test for circular milling. End Mill 3/4" 4 flutes. Speed of spindle 350 R.P.M. Take circular cut 1 1/2" diameter. Max. Error .0002" The specifications including the size and form of the cutter and detailed instructions as to the set up for the machine and the test are very complete.



c d

Fig. 23.18(c) Horizontal Milling Machine.

Slab milling finishing cut to mill the top and bottom faces of a block to a uniform thickness.

C. I. test block -
Brinell Hardness 190 - 210
Size of cut 5 1/2" x 1/8"
Max. Tol. .001" per foot

This test discusses the machining operation and gives detailed information on the type and hardness of the specimen metal together with the depth and thickness of the cut. The method of clamping as depicted by the drawing suggests that an uninterrupted cut is to be preferred.

Fig. 23.18(d) Cylindrical Grinding Machine.

Machine grinds cylindrical between centers. (Convex only)

Diameter 3"
Length 3'
Max. tolerance 0" to .0008"

Symbolic representation of grinding operation between centers. The term "convex only" signifies that steady rests are not used.

Sec. 23.29
Wording of Alignment Test Record Cards

Another feature of the alignment test card that deserves some explanation is the title or heading accompanying each diagram. The heading states briefly the purpose of the test. In this connection, it must be emphasized that a title can be stated in different phrases, each of which means substantially the same thing. This does not mean mere substitution of alternative names i.e. guiding way, positive surface, positive side etc., each of which denotes the same bearing surface.

For example, Fig. 23.19 and Fig. 23.20 represent two methods of obtaining the same information, namely: "Will the axis of a hole bored in a work piece clamped to the table be square with the table top?"

The test shown in Fig. 23.19 seeks this information directly; in Fig. 23.20 the effort is somewhat less direct. Which then is the better? This depends upon other tests which have preceded or will follow it. The alignment of a machine tool must be looked upon as a whole. Each particular step is based upon the assumption that in preceding tests certain alignments have been verified to be correct. In Fig. 23.19 the test presupposes that the work table is square with the column face. Hence the sliding head, if square with the work table, is also parallel with the face of the column.

On the other hand, Fig. 23.20 directly determines the parallelism of the sliding head movement with respect to the column face. Other tests in the sequence will have determined the squareness of the table top to both.

In other words, each test, though valuable in itself, is but a link in a chain. The important consideration is the sufficiency of the sequence. That is, each and every movement of all members, in all possible combinations with other members, must be checked and cross-checked to include all surfaces essential to proper alignment.

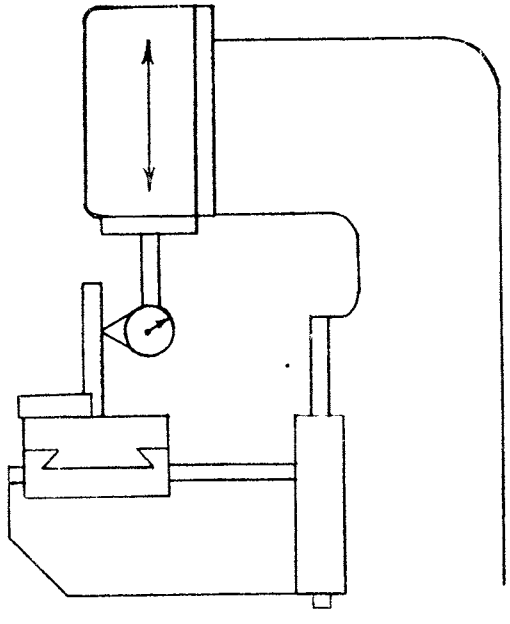


Fig. 23.19 Vertical Milling Machine (Side View).
Vertical adjustment of sliding head square with work table. Max. Tol. .0005" in 8".

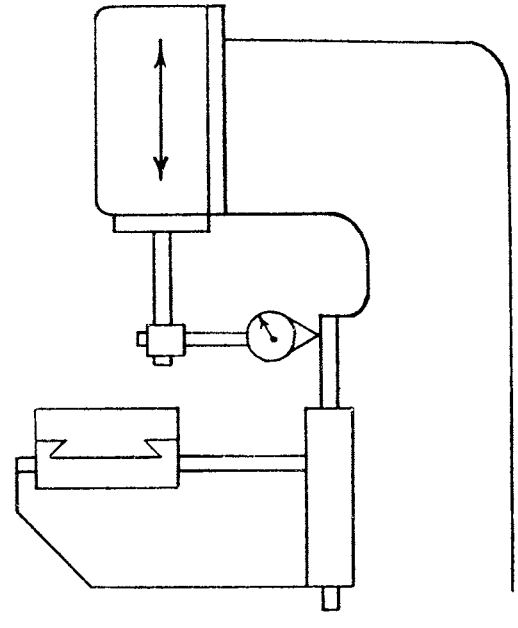


Fig. 23.20 Vertical Milling Machine (Side View).
Sliding head movement parallel with column face. Max. Tol. .0005" in 8".

Chapter 24

THE SURFACE BEARING REQUIREMENTS OF THE SLIDES AND WAYS OF PRECISION GRINDERS

In rescraping a grinding machine a problem is encountered different from any heretofore discussed. A grinding machine is one of the few types of machine tools wherein the work table "floats" on a film of oil. Of the several included in this category it is the one most affected by the characteristics of the bearing surface, which in turn governs to a large extent the choice of lubricant.

The significance of surface bearing quality, particularly as it pertains to PRECISION GRINDERS, lies in the fact that it determines the required oil film. Thicker films of oil mean higher coefficients of friction, greater power loss and more heating. With thin films, on the other hand, there is a risk of metallic contact between the stationary and sliding bearing surfaces.

Sec. 24.1
Essential Surface Bearing Qualities.

Aside from alignments, there are three main requirements which we strive for in scraping-in the table slides, wheel head slides and bed ways of Precision Grinding machines. They are enumerated below:

1. Uniform height of bearing spots from a Datum Plane.
2. Uniform distribution of bearing spots.
3. Adequate number of bearing spots.

These qualifications, it will be noted, are no different than is demanded for the slides and ways of other types of machine tools, except that failure to attain them has more serious consequences in the form of inaccurate dimensions or unsatisfactory surface finish of the work piece. The influence of each of these conditions on the accuracy and finish of the work produced will be discussed in turn.

Sec. 24.2
Uniform Height of Bearing Spots

The importance of flatness in a bearing surface can be shown by an analysis of how this factor affects the efficiency of the machine in grinding the finish on the work piece. For example, the quality of finish is closely related to the condition of the grinding wheel. This in turn is dependent upon the manner in which the wheel is dressed.

A coarse wheel is attained by a rapid traverse of the diamond or other dressing tool across the wheel face. Such a wheel will rapidly remove metal but will produce a rough surface on the work. On the other hand, a finer wheel can be formed by a slow traverse of the diamond across the wheel face.

It is the slow speed of the work table carrying the dressing tool, that necessitates giving special attention to the flatness of the ways of the bed and slides of the table. A bearing surface which is not flat would have a tendency to prevent the work table from sliding smoothly along the ways. At slow speeds the weight of the table tends to squeeze the oil out from between the table slides and bed ways. As the oil film thins, the separation of the slides and ways decreases. In consequence, those bearing spots which are above the bearing plane will rupture this thinner oil film and a metallic contact occurs.

When this happens, two forces act on the work table. First, is the increased friction; and second, is the actuating mechanism. Consequently, the work table moves in a series of jerks, as one force overcomes the other. This condition is most noticeable when the work table moves slowly. In severe cases it is termed "chatter."

The slightest hesitant action of the table is immediately transferred to the wheel face through the dressing tool. Thus the condition of the wheel face directly affects the accuracy and finish of the work. To obtain a high finish, the slowest possible traverse of the wheel is necessary. Therefore the bearing surface of the ways must be uniformly flat to support the weight of the table under the slowest traverse that conditions demand.

To summarize: The hesitance of the work table can be overcome by providing a bearing surface which is all in one plane i.e. has bearing spots of uniform height. This flatness, together with an adequate oil film will prevent metallic contact between the slides and ways.

The requirement of uniform height of bearing spots is also applicable to the wheel head. During in-feed of the wheel, the slides may stick on the transverse ways of the bed. The feeding mechanism then builds up the actuating force until the wheel head breaks loose. The hazard here is that if the feed is augmented even slightly, the wheel head may skip and over-run. Under such conditions it is impossible to produce accurate work.

Sec. 23.3
Uniform Distribution of Bearing Spots

Uniform distribution of bearing spots on the slides and ways is important in maintaining accurate work size. The bearing spots must be spaced so that the weight of the work table is evenly supported at all times. Only thus can the table be maintained at a constant height. Any change in the level of this member, no matter how minute, will affect the accuracy of the work. Unless the bearing spots are uniformly distributed, the table end will dip when passing over an area having inadequate bearing. On the other hand, the table end will rise when sliding over an area having heavier bearing. This change in table height is bound to affect accuracy.

Sec. 24.4
An Adequate Number of Bearing Spots

The third factor influencing the accuracy of precision grinding work is the number of bearing spots on the bearing surface. The percent of bearing usually determines the type of oil to be used, and not vice versa. The kinds and types of lubricating oils in use are so extensive that regardless of the bearing quality scraped into a surface, an oil is always available which will fit existing conditions.

A small number of bearing spots per square inch will require a heavier oil having a strong, thick separating film. This is necessary to prevent metallic contact between the slides and ways. Since there are fewer bearing spots, each must support a proportionately greater part of the table weight. Consequently, a heavy oil is essential to preserve an unbroken film. Should a lighter oil be used on such a surface, the weight of the table on the relatively few bearing spots would be excessive and the oil film would be ruptured. A metallic contact would then be established with unfortunate effects on the accuracy and finish of the work.

It is vital that a uniform table height be maintained. Yet with a heavy oil, the changes in table height under varying conditions of speed, pressure and temperature are such that accuracy of work cannot be satisfactorily preserved. The greater the number of bearing spots per square inch, the lighter the oil may be and the thinner the separating film. The use of a lighter oil will minimize the fluctuation in table height with a resultant improvement in the accuracy of the work.

It is the practice to restrict the viscosity of the lubricant to the lightest bodied oil which is capable of safely supporting the work table i.e. prevention of metallic contact. On this basis, it might be noted, the more bearing spots per square inch on a surface the better. A surface bearing quality of 35 spots per square inch would seem to be very good while a ground or lapped surface with an infinite number of bearing spots would presumably be best of all. The limiting factor is the ability to supply oil to the bearing surface in sufficient quantities at all times. The practicalities of design and cost also limit the percent of bearing scraped into the average precision grinder. Indeed an average of 10 - 20 bearing spots per square inch is adequate for nearly all slides and ways, and precision work of the highest quality can

be ground on this basis. Anything better is superfluous, if not undesirable.

Sometimes the slides and ways of the smaller precision grinder machines, which are hydraulically operated, are lubricated by oil by-passed from the hydraulic system. In this case the character and viscosity of the oil applied to the ways is determined by the requirements of the hydraulic system. It is desirable then to have the bearing quality of the slides and ways conform to the type of oil in use.

Consideration is given to all three factors: flatness, uniform distribution and adequacy of bearing spots when scraping-in a bearing surface. If this is done, and proper lubrication is supplied, the precision grinder will function efficiently and deliver the desired quality of finish and accuracy of work output.

Chapter 25

PROBLEMS IN ALIGNMENTS

Although hand scraping plays a major role in the reconditioning of machine tools, it is by no means the only factor involved in this work. The proper relationship of surface to surface and member to member is also essential. These associations of parts are called alignments. Since alignments have heretofore been touched on but briefly, it may be well to introduce this subject in a simple yet practical way.

Virtually every machine tool can be broken down into elementary forms that are, in themselves, not difficult to scrape. When this basic simplicity has been discovered, all scraping and aligning operations become largely a process of combination, or selection. It is difficult for the novice to see the significance of this, but with continued scraping experience he comes to apply this analysis in all manner of jobs almost instinctively and without effort.

The bewildering variety of machine tools is likely to confuse the novice until experience shows him that nearly every type, no matter how complex, may be treated similarly to one of the basic forms. Consequently, even though the number of variations not counting size, in daily use, run into many hundreds, it is still possible, by following the principles and procedures outlined, to cope with any type of tool, even the most complex.

In the following series of problems all the commonly used forms of bearing surfaces are described. The scraping routine and tests to be made on representative machine members will also be discussed. Each member illustrated will be treated individually, employing as spotting tools and test gages only standard accessories.

The operator should understand that the condition of the tool or gage, entirely apart from the skill employed in using it, affects the accuracy of the tests. Consequently, as the number of gages combined together for a set up increases, so also does the probability of error. The operator should, therefore, promote accuracy by utilizing the very minimum of apparatus.

Before taking up these problems it should be noted that the OBJECTIVES make no mention that a given surface when scrape-finished must be flat and straight. This much is understood. Furthermore, the quality of surface bearing, which is a very important consideration in actual practice, is not specified since there could be a very wide variation in requirements between kinds of machines and even between different members of the same machine.

Sec. 25.1

OBJECTIVES: Two Flat Surfaces in the same plane.

1. Bearing surfaces (A-A') to be parallel.

PROCEDURE:

A machine member featured by two bearing surfaces side by side, as shown in Fig. 25.1, can be dealt with in much the same manner as a single flat surface. For spotting such a pair of surfaces it is good practice to alternate between a SURFACE PLATE and a STRAIGHT EDGE. If properly manipulated, the tools are capable of accurately transferring the marking compound to the bearing surfaces.

During the entire operation a constant check should be kept on the flat ways to detect both convexity and "wind". This is best done by conducting the Spin Test and the "X" Test at regular intervals. These are the quickest and most accurate means for discovering either condition. Fig. 25.1 shows the "X" Test being performed.

On this type of surface the uniform distribution and coloration of the markings after the final spotting cycle denotes the realization of the OBJECTIVE.

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On this type of surface the uniform distribution and coloration of the markings after the final spotting cycle denotes the realization of the OBJECTIVE.

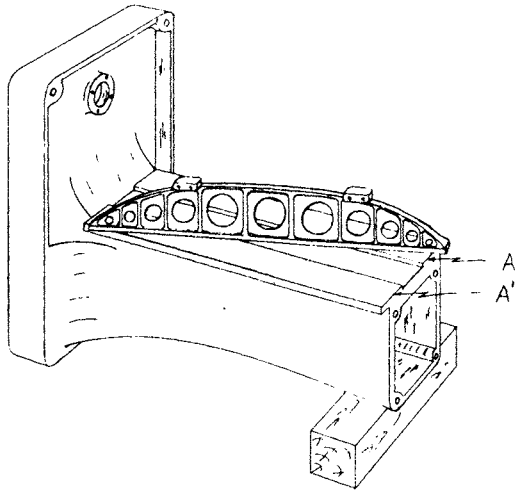

Fig. 25.1 Divided flat ways must be treated as one plane. Application of the X test with a STRAIGHT EDGE is an appropriate check on convexity.

(A - A') flat ways.

Sec. 25.2

OBJECTIVES: Flat Surface square with adjacent surface.

1. Surface (B) to be square with the scrape-finished surface (A).

PROCEDURE:

For efficient handling of the problem posed, the member should be turned so that surface (B) is uppermost, as represented in Fig. 25.2. In this position the surface is most easily scraped and tested. Assuming in our imaginary case that surface (B) is both long and narrow, a STRAIGHT EDGE would be most suitable for applying the marking compound during a spotting cycle. Caution should be exercised in handling the tool to avoid lateral tilting and resultant false markings.

A RIGHT ANGLE TEMPLATE is used to help keep the surface (B) square with scrape-finished surface (A) which is the check point. This tool is also of assistance in preventing the edges of surface (B) from becoming rounded. It is good practice always to alternate these tools when spotting the surface as the inadequacies of one are compensated for by the superior qualifications of the other. The realization of the OBJECTIVE is proved by a uniform distribution and coloration of the markings.

Incidentally, either a TOOL MAKER'S SQUARE or a vernier protractor can be substituted to check surface (B) for squareness with surface (A) but the TEMPLATE mentioned above is preferable under the conditions described, as it makes for greater speed and accuracy. Refer to Sec. 12.4.

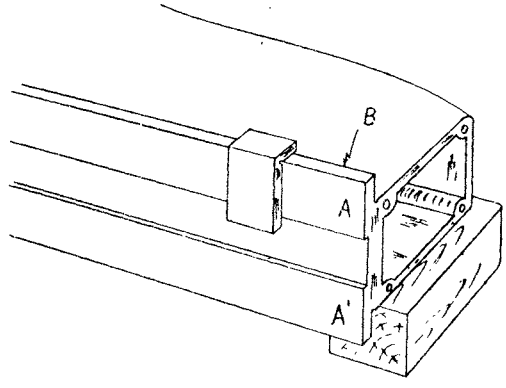

Fig. 25.2 Showing application of RIGHT ANGLE TEMPLATE to keep a surface square with adjacent flat ways.

(A - A') scrape-finished flat ways (B) surface being treated.

CAUTION:

Exercise special care in scraping along the edges of this narrow surface to avoid rounding them.

Sec. 25.3

OBJECTIVES: Flat Surface parallel with another surface.

1. Surface (C) to be square with surfaces (A-A').
2. Surface (C) to be parallel to surface (B).

PROCEDURE:

Since this is a continuation of the previously discussed problem, surfaces (A), (A'), and (B) are assumed to be scrape-finished. Thus we are provided with convenient check points.

The first step in dealing with the present problem is to place the machine member so that surface (C) is uppermost, as illustrated in Fig. 25.3. Surface (C) is spotted with a STRAIGHT EDGE and a RIGHT ANGLE TEMPLATE used alternately. All the precautions for dealing with this type of surface, previously suggested in Sec. 25.2, should be observed

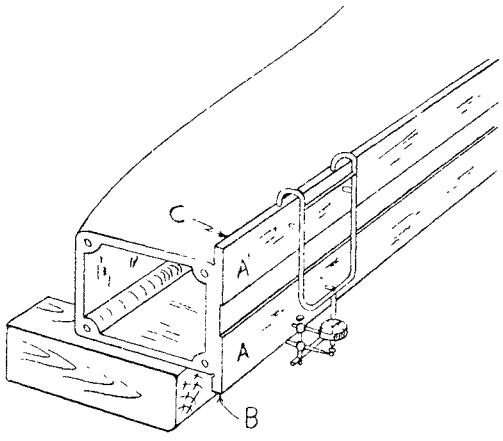

Fig. 25.3 Method of using INDICATING JIG and DIAL INDICATOR to check parallelism of two surfaces.

(A - A') scrape-finished flat ways (B) scrape-finished square edge (C) surface to be tested.

in the present instance so that fulfillment of OBJECTIVE NO. 1 will be expedited.

If surface (C) is seen to be roughly machined, or heavily worn, good practice favors undertaking one or two conventional spotting and scraping cycles in order to prepare a fairly flat plane suitable for preliminary testing for parallelism.

When this physical condition is in readiness, an indicating jig with attached DIAL is placed on the surfaces in the manner shown in Fig. 25.3. Greater stability is afforded the device by allowing surface (C) to support the weight. Surface (C) is thereby tested indirectly as the contact point indicates surface (B). By moving the jig the length of the work piece, the reading is obtained. Any change in the pointer indicates divergence. That is to say, it shows that surface (C) is not parallel to surface (B). This condition must be corrected for any indicated deviation, either plus or minus. The end of the surface showing the greater divergence from (B) has an excess of metal. Consequently, it is scraped heavier to make surface (C) parallel to surface (B). In this way OBJECTIVE NO. 2 is realized.

Of the two OBJECTIVES, parallelism is the more critical requirement because, if insufficient, it will either cause binding or induce slack in the mateing member, depending upon the direction the sliding part is moved. This OBJECTIVE is also more difficult to achieve and therefore some tolerance is usually allowed when aligning such a surface. Both OBJECTIVES must be completed simultaneously.

There are alternative methods of checking for parallelism by use of either an outside micrometer or a vernier caliper. However, unless the operator is adept at measuring between widely separated points with these tools, it is better to employ the indicating jig in conjunction with a DIAL INDICATOR. The latter system usually is preferred by the average operator because for him it is faster, more accurate, and more dependable.

Sec. 25.4

OBJECTIVES: Flat surface parallel with another surface.

1. Bearing surfaces (D-D') to be parallel to (A-A').

PROCEDURE:

The most practicable plan in dealing with this case is to turn the member so that it is in the position shown in Fig. 25.4, that is, with surfaces (D-D') on top. Either surface can be worked first, as they are checked against a scrape-finished surface (A-A') and not against each other. The treatment accorded both surfaces is identical.

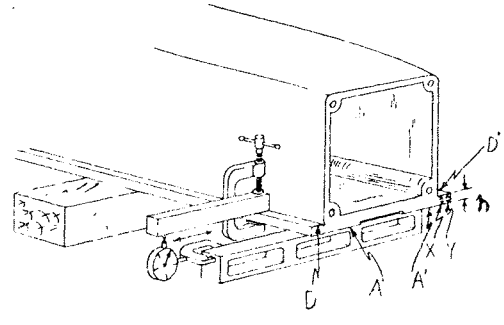

Fig. 25.4 Showing method of using a PARALLEL to extend a narrow surface being tested for parallelism.

(A - A') scrape-finished surface (D - D') narrow surfaces being tested (h) thickness dimension (X - Y) lines of measurement if micrometer is used.

Spotting is accomplished with either a standard STRAIGHT EDGE, if there is ample room, or with an ANGLE STRAIGHT EDGE when space is restricted. It is assumed that the surfaces

(D-D') will be scraped reasonably flat before executing the following tests:

If a specified thickness dimension, such as (h), is required, measurements can be made from time to time with a micrometer to keep tab on the progress of the scraping. An approximate check on parallelism of (D') to (A') can also be made with the micrometer by measuring through lines (X) and (Y) and comparing the readings. Several measurements should be made from end to end of the surfaces.

Although the method above described is not a very accurate test for parallelism because of the comparatively short distance separating (X) and (Y), it will be found sufficiently so for ordinary purposes. When greater precision is wanted, the set up shown in Fig. 25.4 can be applied. Here a PARALLEL is clamped to (D). Then a DIAL INDICATOR attached to a SCRAPED PARALLEL is moved on surfaces (A-A') in the direction indicated by the arrow. Any variation in the DIAL reading means that surface (D) deviates from parallelism with surfaces (A-A'). Readings should be taken on (D-D') at both ends of the member and at several intermediate points.

The accuracy of the latter test is high because the greater extension of the PARALLEL, as compared to the relatively narrow width of surfaces (D-D'), reveals differences more noticeably.

Sec. 25.5

OBJECTIVES: Flat Surfaces separated by an obstruction.

1. Surfaces (B-C) to be parallel.

PROCEDURE:

An analysis of the construction shown in Fig. 25.5 suggests that previously discussed methods of scraping two flat bearings are not appropriate in the present instance. The nature of obstruction (A) prohibits the use of either a SURFACE PLATE or STRAIGHT EDGE for spotting the two surfaces simultaneously. On the other hand, it would not be practical to deal with one surface and then employ it as a Check Point to align the other surface. For the sake of efficiency, it is preferable to treat both of these surfaces at the same time.

The initial step in solving the problem is to establish a Check Point for surfaces (B) and (C), seen in Fig. 25.5. The simplest plan is to employ a convenient structural feature, which in the example shown would be surface (A).

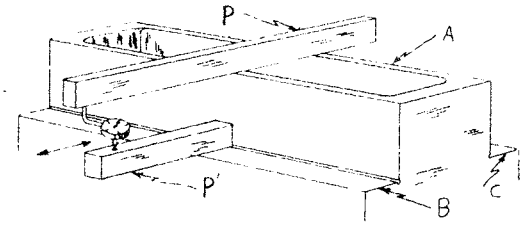

Fig. 25.5 Using PARALLELS to test parallelism of flat ways separated by an obstruction.

(P) long PARALLEL (P') short PARALLEL
(A) raised surface dividing (B) from (C)
(B - C) flat ways.

To prepare it for such usage, first remove all burrs. Next scrape surface (A) flat and impart a quality of about 4 - 5 bearing spots per square inch. (A SURFACE PLATE would be the logical tool to use for spotting.) With this accomplished we have established a Check Point.

Now turning to surfaces (B) and (C) a STRAIGHT EDGE is applied to spot them. After one or two scraping cycles, the surfaces should be tested for parallelism as follows:

A DIAL INDICATOR is fastened to a long PARALLEL (P) laid cross-wise on surface (A). The contact button is adjusted to touch a shorter PARALLEL (P') which is held on surface (B), as represented in Fig. 25.5. The large PARALLEL (P) is moved transversely as shown by the arrow, and DIAL readings are taken from end to end of the PARALLEL (P').

Next the set-up is transferred to surface (C) for a comparable check. Readings are taken at several positions from end to end of the surface. The results of these tests must be identical before the two bearings (B) and (C) are parallel in the vertical plane measured in the transverse direction.

While the action described in the paragraphs above is taking place, simultaneous checks for parallelism must also be made in the longitudinal direction as follows:

A PARALLEL (P) is laid cross-wise on surface (A), as illustrated in Fig. 25.6. After fastening a DIAL INDICATOR in any

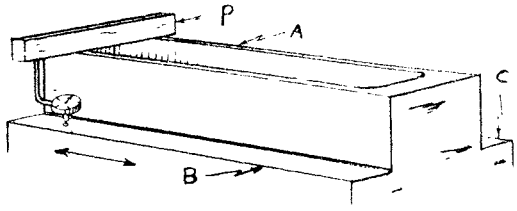

Fig. 25.6 Method of using PARALLEL and DIAL INDICATOR to check surfaces (B) and (C) for parallelism in the vertical plane with reference surface (A).

(P) PARALLEL (A) reference surface
(B - C) flat ways to be tested.

convenient manner to the PARALLEL and adjusting the button to touch surface (B), the device is slid lengthwise along surface (A). The reading of the DIAL is noted as it registers the variation from end to end of surface (B). (See NOTE:) The apparatus is next moved to the other side of the casting, and surface (C) is indicated in like manner. A comparison of the two readings will show the amount and direction of deviation from parallelism in the longitudinal direction.

Both procedures, illustrated in Figs. 25.5 and 25.6, are frequently used during the scraping operation to disclose the rate of progress. OBJECTIVE NO. 1 is satisfied when a zero-zero reading is obtained at all points on Surfaces (B) and (C).

NOTE:

In moving the DIAL from end to end of the surface, try to keep the button at a constant distance from the edge, or preferably on the center line. This area, midway between the edges, is apt to be the most carefully scraped portion. A second and more important reason for doing this is to assure peak accuracy in case surface (B) varies from strict parallelism with surface (A), as measured in the transverse direction.

Sec. 25.6

OBJECTIVES: Flat Surfaces separated by an obstruction.

1. Surfaces (B-C) to be parallel.

PROCEDURE:

The difficulty here is somewhat similar to that discussed previously in Sec. 25.5. However, to pose a new situation and thereby broaden the reader's experience, a design such as shown in Fig. 25.7 will be adopted. From the form of obstruction (A) it is obvious that it cannot be used as a check point. Another practicable method of aligning the bearings, utilizing a SURFACE PLATE as a DATUM POINT, will be demonstrated instead.

An ANGLE STRAIGHT EDGE is the appropriate tool for spotting the bearing surfaces. All spotting, scraping and testing for alignment will be conducted with the casting set on the SURFACE PLATE.

Several spotting and scraping cycles should be executed prior to any testing for alignments. This practice will provide a relatively smooth and flat surface from which the initial testing may proceed.

Certain alignment tests are then conducted to ascertain the amount of misalignment. Since we wish to have surfaces (B-C) aligned in both the longitudinal and transverse directions it will require two operations to check parallelism. They should be repeated at intervals during the scraping process to determine progress, and finally to prove the attainment of the OBJECTIVE.

The essential checks are performed as follows:

Place the member on a SURFACE PLATE (see NOTE). Lay a PRECISION LEVEL longitudinally on one of the flat bearing surfaces, (B) for example. Shim the casting until the bubble in the glass vial is centered. Then move the LEVEL over to a corresponding position on the other flat slide (C). If the bubble is centered there also, both bearings are parallel in the vertical plane, measured longitudinally. Should this reading not be identical, scraping is continued on one or both surfaces to correct the error and to develop the desired bearing quality. However, before this operation is begun, it is advisable to make a check in the other direction as follows:

Hold a PARALLEL cross-wise on one flat slide, say (B) as represented in Fig. 25.7. Set a Surface Gage with attached DIAL INDICATOR on the SURFACE PLATE. Place the button of the instrument in contact with the PARALLEL at the center-line, and move it back and forth between (e-e') as indicated by the arrow. Take a reading at both points. If

this reading is not zero-zero, additional shims are placed under the casting until it is attained.

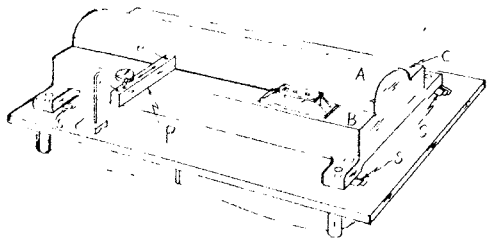

Fig. 25.7 Method of measuring from a SURFACE PLATE with Surface Gage and attached DIAL INDICATOR to test flat surfaces for parallelism.

(A) Obstruction (B - C) flat surfaces to be tested (P) PARALLEL employed to extend surfaces (e - e') points of measurement on PARALLEL (S) Shim stock.

The PARALLEL and other apparatus are then moved to a corresponding position on the opposite bearing surface (C) where the test is repeated. If this, too, is zero-zero the bearings are parallel in the vertical plane measuring in the transverse direction.

For purposes of clarity the procedure attending each check for parallelism has been explained separately, but in actual practice, the checks would be repeated successively and repetitiously. The sequence of alternate testing, spotting, and scraping must be correlated and so executed that the final result of the checks i.e. the OBJECTIVE, is attained expeditiously.

Incidentally, if for any reason it is necessary to keep both surfaces at the same level or height from the base pads of the casting, the DIAL readings in addition to being zero-zero must also be identical in all cases.

NOTE:

Placing copper strips under the four pads of the casting will preclude scoring of the SURFACE PLATE.

Sec. 25.7

Alternative Methods of Testing for Parallelism surfaces separated by an Obstruction.

To determine whether two surfaces are or are not parallel, several practical tests, which differ from those previously described in that they do not utilize an established Check Point or Datum Point, are available. Three of these tests will be discussed briefly, as follows:

1. Fig. 25.8 shows two equal size, scraped PARALLELS arranged opposite each other at the same end of the surfaces designated (B) and (C). The dimensions of the PARALLELS should be sufficient to permit clearance above surface (A). By applying a film of marking compound to a STRAIGHT EDGE and then spotting the tool across the PARALLELS, markings are transferred. When the markings on each PARALLEL are uniform in shading and distribution, it denotes that the surfaces (B) and (C) are, practically speaking, parallel in the transverse direction at the location checked. We say "practically speaking" because in spite of careful manipulation some slight error may be present in the set up. For example, the coating of marking medium spread on the tool may not be uniform overall. However, by spotting the STRAIGHT EDGE several times in this way, progressively moving the PARALLELS from the far to the near end of the casting, surfaces (B) and (C) will be adequately tested for parallelism in the transverse direction. This series of spottings from end to end will also indicate to what extent the test surfaces are parallel measuring longitudinally.

Parallelism in the vertical plane between (B) and (C) will be known to exist if

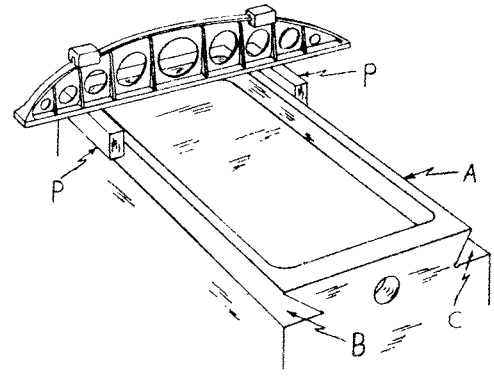

Fig. 25.8 Using STRAIGHT EDGE and pair of matched PARALLELS to test parallelism of two surfaces separated by an obstruction.

(A) Obstruction (B - C) surfaces to be tested (P) scraped PARALLELS.

the markings are uniform and do not vary at each new position tested. To obtain the maximum information from this procedure the markings must be carefully compared after each spotting cycle.

As a variation of this plan, the STRAIGHT EDGE could be applied to the PARALLELS in a criss-cross manner i.e. the X Test (Sec. 22.2).

2. The degree of parallelism in the longitudinal direction between two surfaces may be determined without regard to a verified Check Point by employing the set-up illustrated in Fig. 25.9. This requires a PARALLEL to be laid on surface (B) and another to be placed on surface (C). A clamp, rod and DIAL INDICATOR are attached to one PARALLEL, as shown. The obstruction (A) is bridged and the DIAL button is adjusted to touch the second PARALLEL. Readings are taken with the PARALLELS first positioned at one end of the work surface, then at the other end. A zero-zero reading at all locations indicates that surfaces (B) and (C) are parallel in the direction tested.

To test in the transverse direction surfaces (B) and (C) must be spotted by the scrape-finished mateing member, and the accuracy determined by the uniformity of the markings. Tests in both directions are applied alternately during the scraping process.

3. In cases where the obstruction (A) is quite wide, the previously described set-up involving the use of a DIAL INDICATOR becomes increasingly impractical on account of the exaggerated length of the rod arm required. To preserve balance it would be necessary to employ

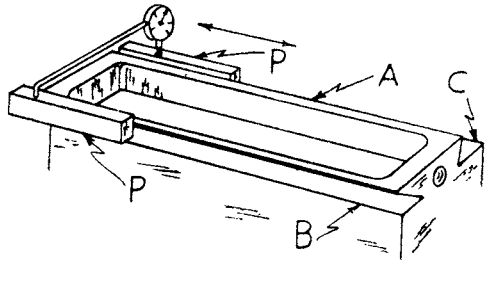

Fig. 25.9 Method of using two PARALLELS and DIAL INDICATOR to test parallelism in the longitudinal direction.

(A) Obstruction (B - C) surfaces to be tested
(P) PARALLEL.

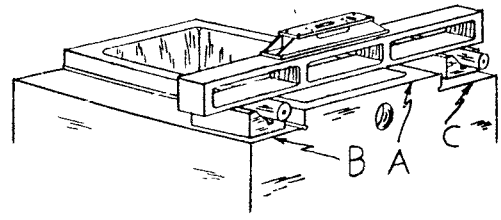

Fig. 25.10 Employing V-blocks and PRECISION CYLINDERS to elevate the bridging PARALLEL and LEVEL.

(A) Obstruction (B - C) surfaces being tested for parallelism.

counter weights. This practice which can easily lead to errors is never employed if alternative equipment is available.

A better method of bridging widely separated surfaces is illustrated in Fig. 25.10. Here Vee blocks, and hardened and ground cylindrical test bars are combined in a set-up which will bridge surface (A). The apparatus consists of a PARALLEL positioned as shown and a PRECISION LEVEL placed on top.

With the equipment arranged at one end of the casting, the bubble in the glass vial should be centered. This may be easily accomplished by interposing the necessary amount of shim stock between one CYLINDER and PARALLEL.

The test is repeated with the same apparatus, including shim stock, at the other end of surfaces (B) and (C). If there is no displacement of the bubble, it indicates that the surfaces are parallel measuring longitudinally. This assumes the absence of transverse taper. This condition may be checked by spotting with a mateing member or by other methods suitable to the situation.

The method just described may be adopted to bridge widely separated bearings such as are found on planer beds. The accuracy attainable is limited only by the precision of the gages and instruments utilized.

Sec. 25.8

OBJECTIVES: Flat Surfaces at different levels.

1. Surface (D) to be parallel to surfaces (B) and (C).

PROCEDURE:

A study of the drawing shown in Fig. 25.11 will familiarize the operator with a

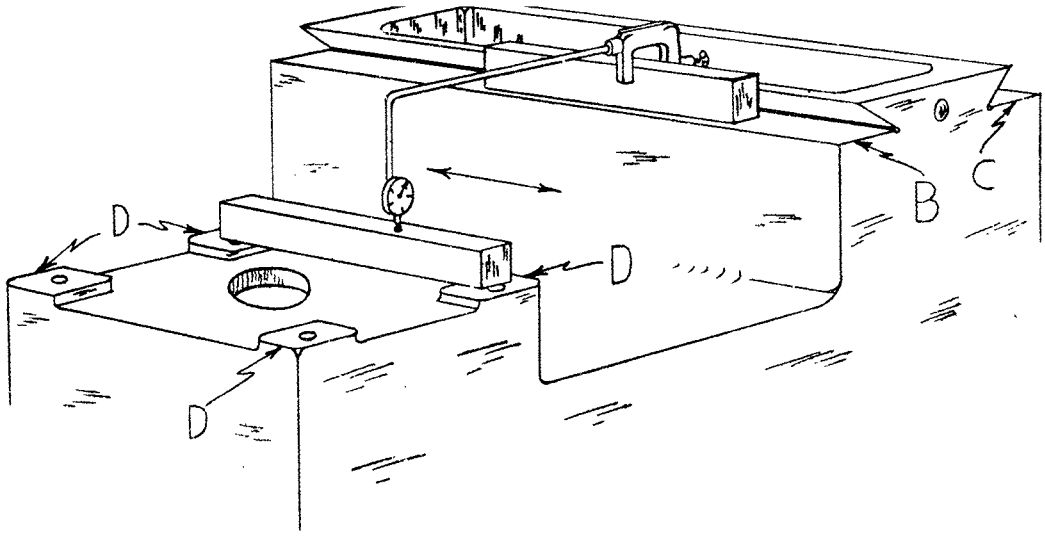

Fig. 25.11 Method of using PARALLELS and DIAL INDICATOR to test for parallelism surfaces remote and at a different level than the Datum Plane. Apparatus checks longitudinally.

(B - C) Scrape-finished surfaces (DATUM PLANE) (D) pads to be made flat and parallel to DATUM PLANE.

problem that is occasionally encountered. The similarity of the construction at the right (surfaces (B) and (C)) to a previous problem discussed in Sec. 25.7 is unmistakable. Equally obvious is the fact that these bearings must be dealt with first, in order to provide a reliable check point. If this is done, we can treat the pads comprising surface (D) as follows:

A SURFACE PLATE is utilized for spotting. The results of the scraping effort are tested frequently so that the operator knows at all times in which direction to tilt the surface by scraping to obtain correct alignment. This systematic testing is essential in order to develop pad surfaces (D) parallel to (B-C).

The test for parallelism in the longitudinal direction requires a set up like that shown in Fig. 25.11. One PARALLEL is laid across pads (D) as indicated, and another PARALLEL with DIAL INDICATOR attached is placed lengthwise on surface (B). The button of the instrument is adjusted to touch the PARALLEL first mentioned. Next the INDICATOR apparatus is moved lengthwise along surface (B) and the results are recorded. A zero-zero reading is requisite.

Preparation for testing parallelism in the transverse direction is made by placing identical PARALLELS on surfaces (B) and (C) and laying a SCRAPED PARALLEL or STRAIGHT EDGE across them, as illustrated in Fig. 25.12. Another PARALLEL, mounting a DIAL INDICATOR, is set across the pads (D) as shown. The contact button of the instrument is located against the under surface of the SCRAPED PARALLEL, then moved as far as conditions permit in the direction shown by arrow. The reading obtained is recorded. Next the testing tools are reset so that the pads at the other end of the surface can also be checked. Repeat the test and again make a note of the results. A zero-zero reading is required.

These two tests executed successively will indicate either the attainment of parallelism, or the deviation from it, in both the longitudinal and transverse directions, respectively.

If the distance between the two surfaces (D) and (B-C) is so wide the demonstrated mechanical method is unwieldy, a PRECISION LEVEL can be employed as an alternative check for parallelism. The LEVEL should be laid on surfaces (B), (C), and (D) longitudinally and transversely.

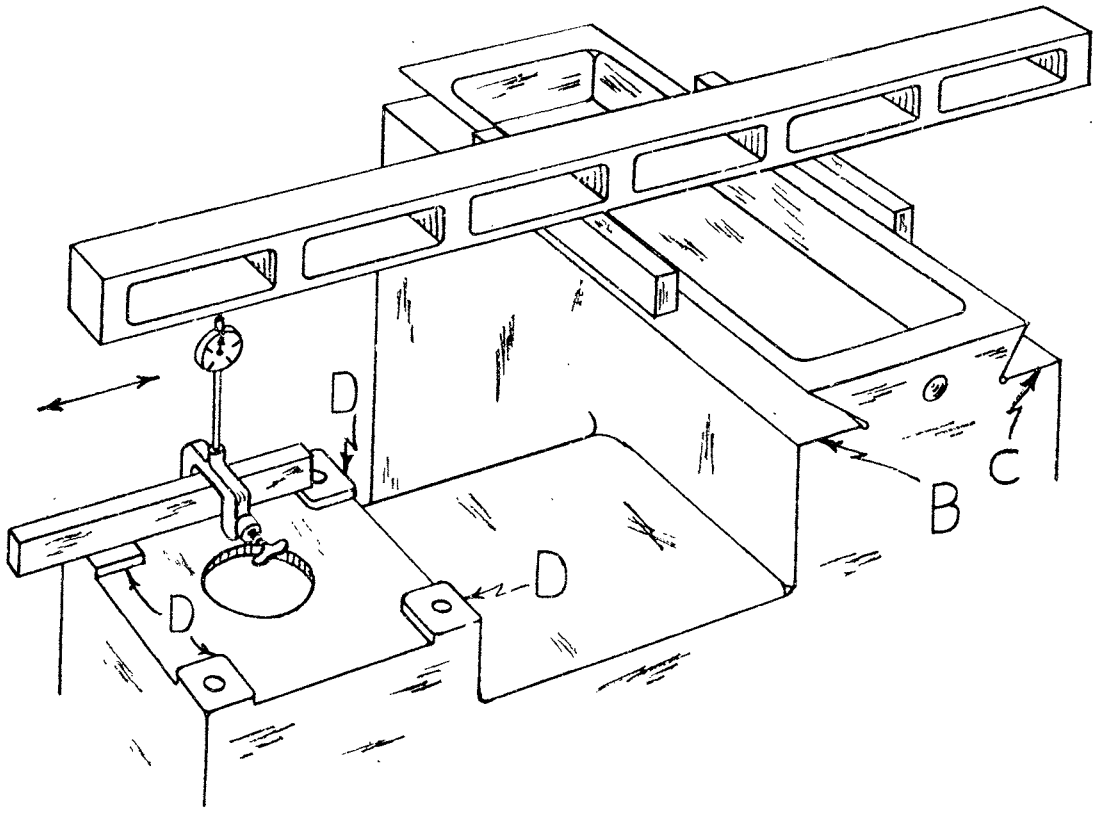

Fig. 25.12 Showing method of testing surfaces for parallelism measuring from a Datum Plane situated at a different level. Apparatus checks transversely.

(B - C) Scrape-finished Datum Plane (D) surface pads to be made flat and parallel to Datum Plane.

Sec. 25.9
OBJECTIVES: Male dovetail.

1. Horizontal bearings (A-A') to be parallel.
2. Angular surfaces (B-C) to be parallel.
3. Angular surfaces (B-C) to be equally inclined with respect to the horizontal bearings.

PROCEDURE:

Attention is directed first of all to surfaces (A-A') which should be scrape-finished and aligned according to the methods proposed in preceding sections. When OBJECTIVE NO. 1 is achieved, horizontal surfaces (A-A') will constitute the Check Point for the angular surfaces.

After selecting the guiding surface, assumed in this example to be (B), the member is adjusted so that it is in the most convenient working position consistent with its size and weight. The slanting dovetail side (B) is spotted most easily with an ANGLE STRAIGHT EDGE applied in the manner described in Sec. 9.17. If surface (B) must be formed to a definite angle with surface (A), make up a MALE DOVETAIL TEMPLATE to the specified dimensions and apply it alternately for spotting. (See Fig. 25.13) Incidentally, a Vernier Protractor could be substituted, though as explained in Sec. 4.3, it is not so satisfactory. Dovetail surface (B) is scraped until it shows the required surface bearing quality, whereupon it is considered completed.

To treat the other dovetail side, surface (C), the casting is inverted so that this surface is likewise placed in the correct spotting and scraping position. The above mentioned tools are again used for spotting. There would be no change in

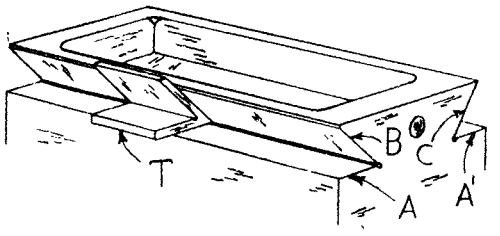

Fig. 25.13 Method of spotting angular dovetail surfaces using DOVETAIL TEMPLATE.

(A - A') Scrape-finished flat ways (B - C) Angular dovetail surfaces (T) TEMPLATE

the routine of dealing with this surface except for one new factor, namely; surface (C) must be parallel to surface (B).

A check for parallelism in the longitudinal direction can be made with a DIAL INDICATOR attached to a jig constructed as shown in Fig. 25.14. This apparatus is moved from end to end of the bearings meanwhile noting the readings. Scraping and checking operations are conducted alternately until parallelism is realized, as indicated by a zero-zero reading. OBJECTIVES NO. 2 and NO. 3 must be attained simultaneously since they pertain to the same surface. The MALE DOVETAIL TEMPLATE, previously referred to, is instrumental in maintaining an exact angle.

If the distance to be spanned is not excessive, an alternative method of testing parallelism employing either the micrometer or the vernier caliper is practicable. With this system hardened and precision ground cylinders are placed in the dovetail at one end, as shown in Fig. 25.15. Then the measurement is made across them. This check is repeated with the apparatus situated at the opposite end of the member. Identical readings signify correct alignment. With this type of dovetail such a test is feasible because each cylinder rests against two scrape-finished surfaces.

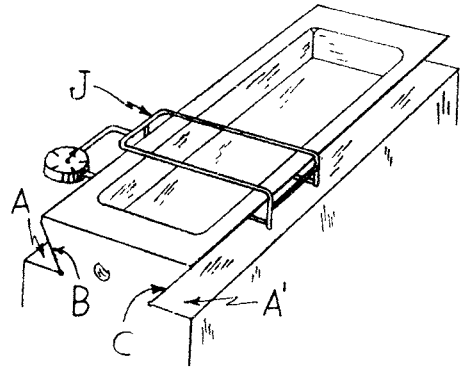

Fig. 25.14 Checking parallelism of dovetails using INDICATING JIG and DIAL INDICATOR.

(A - A') Scrape-finished flat ways (B) scrape-finished dovetail side (C) surface being aligned to (B) (J) Jig

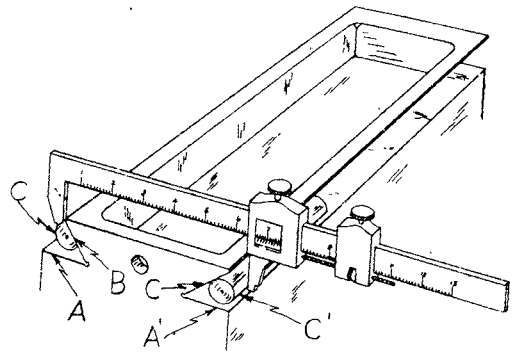

Fig. 25.15 Testing parallelism of dovetails using matched PRECISION CYLINDERS and vernier caliper.

(A - A') Scrape-finished surfaces (B-C) angular dovetail surfaces being tested (c-c') cylinders.

Sec. 25.10
OBJECTIVES: Male Dovetail.

1. Horizontal bearing (A) to be flat.
2. Angular surfaces (B-C) to be equally inclined with respect to the horizontal bearing.
3. Angular surfaces (B-C) to be parallel.

PROCEDURE:

Flat surface (A)

Fig. 25.17 shows the casting in its normal setting with surface (A) in the preferred horizontal spotting position. Surface (A) is now spotted by alternate applications of the SURFACE PLATE and STRAIGHT EDGE. Scraping should be continued until colored markings are uniformly distributed indicating that OBJECTIVE NO. 1 is achieved. Surface (A) now becomes the DATUM PLANE for the other surfaces.

Dovetail Side (B)

After completing surface (A), turn the work piece so that dovetail side (B), assumed here to be the guiding surface, is uppermost and convenient for scraping. The reason for tilting surface (B) is to provide a position enabling the spotting

tool to utilize part of its weight to transfer marking compound. This makes for greater accuracy. However, if turning the member isn't feasible on account of its design or weight, then the spotting tool must be pressed upward against the surface to transfer the marking medium. This is an exceedingly awkward and difficult spotting position, one which easily leads to false markings unless extra care is exercised.

Usually, owing to space limitations, an ANGLE STRAIGHT EDGE is the appropriate tool for spotting dovetail side (B). Since it is necessary to form a definite angular inclination between (B) and (A) (OBJECTIVE NO. 2), it is advisable to alternate with a MALE DOVETAIL TEMPLATE represented in Fig. 25.16. Thus one tool indicates the angle while the other registers the flatness of the surface.

Dovetail Side (C)

We now invert the casting so that surface (C) has the same approximate position previously occupied by surface (B). The ANGLE STRAIGHT EDGE and the MALE DOVETAIL TEMPLATE utilized on the surface previously dealt with, may again be applied alternately to spot (C). If used in this fashion, they effectively generate flatness and the correct angle in (C), as required by OBJECTIVE NO. 2.

While conducting these operations it is advisable to make frequent checks of the parallelism of (C) against (B), as demonstrated in the set up shown in Fig. 25.17. These tests should be made periodically during the scraping operations on (C). An indicating jig with attached DIAL INDICATOR is required. As the device is moved along the dovetail, from end to end, any divergence from parallelism will be shown by variations of the DIAL pointer. Scraping cannot be terminated until parallelism is attained. This satisfies OBJECTIVE NO. 3.

Due to the special design of this type of male dovetail, the indicating jig, or modifications of it, with attached DIAL INDICATOR, is the only practical device for checking parallelism. Hardened, ground steel cylinders obviously cannot be used as in the problem discussed in Sec. 25.9.

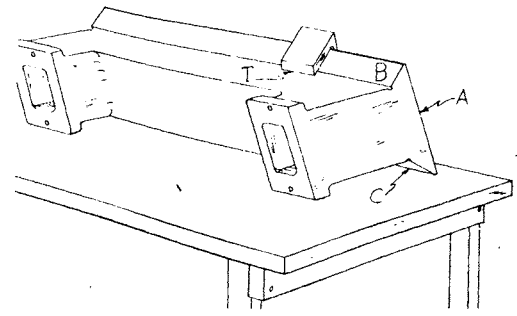

Fig. 25.16 Preferred method of positioning casting to facilitate spotting and scraping the angular surfaces of male dovetail.

(A) flat way (B-C) angular dovetail surfaces (T) template

Sec. 25.11

OBJECTIVES: Female Dovetail.

1. Horizontal bearing (A) to be flat.
2. Angular surfaces (B) and (C) to be equally inclined with respect to the horizontal bearing.

PROCEDURE:

To demonstrate the scraping and alignment problem involved in the type of Female Dovetail illustrated in Fig. 25.18, a a sliding machine member is utilized. Reference to the figure will show that provision is made in the design of this female dovetail sliding member for a tapered gib to be attached (or gibbed) to surface (C). Consequently, it is not essential for the gibbed surface to be parallel to (B).

The horizontal flat slide (A) will be the Check Point of the other surfaces, and consequently it is the first surface dealt

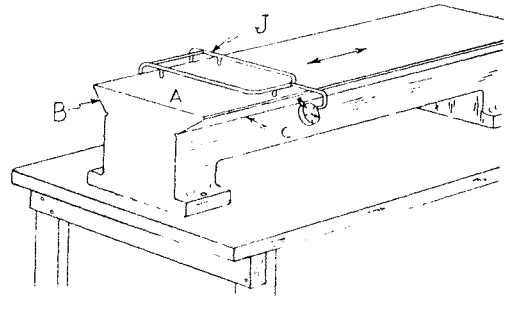

Fig. 25.17 Testing angular surfaces of male dovetail for parallelism by means of INDICATING JIG and DIAL INDICATOR.

(A) flat way (B-C) angular surfaces to be tested for parallelism (J) jig

with. To spot surface (A) calls for a template of special design to fit between the dovetail surfaces (B) and (C). Such a gage could, of course, be made but would be an expensive undertaking. Fortunately, the stationary member would have been scrape-finished beforehand and thus the flat way (X) in Fig. 25.19 may be used in lieu of a special spotting template. We must assume that the other surfaces of the stationary member designated (Y) and (Z) in the same figure, also are correctly aligned and scrape-finished.

Spotting is accomplished by coating the flat way (X) with marking medium, and then carefully placing the sliding member on top. The compound is transferred to flat slide (A) in the usual manner. All precautions listed under Sec. 12.19 (Spotting technique with a Mateing Member) should be observed. This process combined with careful scraping will effect OBJECTIVE NO. 1. Incidentally, the OBJECTIVE could also be phrased as "Flat slide (A) to be fitted to flat way (X)."

After the male dovetail side (Y) or guiding way of the stationary member, has been coated with compound it can be used to spot the female dovetail side (B), or guided slide, shown in Fig. 25.18 and Fig. 25.19. When a satisfactory bearing surface is achieved by alternate cycles of careful spotting and scraping dovetail side (B) is assumed to be done. Thus a part of OBJECTIVE NO. 2 is discharged.

The balance of OBJECTIVE NO. 2 can be realized most perfectly if we interrupt our routine at this point to construct a small hand TEMPLATE (T) using as a pattern the MALE DOVETAIL TEMPLATE described previously in Sec. 25.10, and shown in Fig. 25.16. We could also form TEMPLATE (T) on surface (B) as shown in Fig. 25.18. Such a TEMPLATE if accurately made and applied, will succeed in matching the included angle (C-A) to the included angle (Z-X). The more exactly we do this the more we simplify the subsequent job of fitting the tapered gib piece into the slot between gibbed surface (C) and gib way (Z). (In lieu of constructing a TEMPLATE a Vernier Protractor could be used though not so satisfactorily.) Spotting alternately with an ANGLE STRAIGHT EDGE is required to maintain flatness.

Both OBJECTIVES must be completed simultaneously.

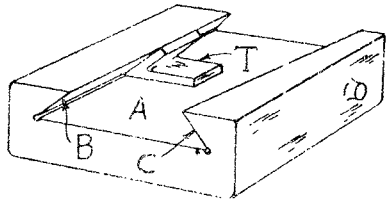

Fig. 25.18 Forming a TEMPLATE on scrape-finished surfaces of Female Dovetail

(A) Flat slide (first surface scraped)
(B) Guided slide (second surface scraped)
(C) Gibbed surface (final surface scraped)
(T) Template

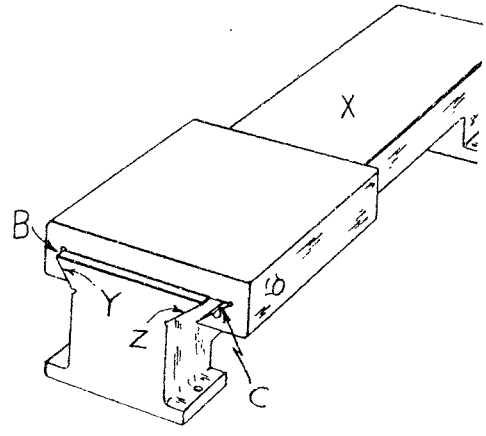

Fig. 25.19 Method of spotting flat slide (A) of sliding member using the scrape-finished flat way (X) of the stationary member as a spotting template. Guiding way (Y) can spot guided slide (B) and Gib way (Z) can spot gibbed surface (C) in turn.

(A) flat slide of female dovetail (B-C) angular surfaces of female dovetail (X) flat way of male dovetail (Y-Z) angular surfaces of male dovetail.

NOTE:

The critical reader may have questioned the need for constructing a special TEMPLATE to form surface (C) to the exact angle of surface (Z). With so elementary a design incorporated in the sliding member, it would seem to be a simple matter to spot surface (C) directly from surface (Z) by swiveling the casting. However, the procedure outlined above will be appropriate for the many cases when, due to design factors, it is impossible to swivel the casting.

Sec. 25.12
OBJECTIVES: Female Dovetail.

1. Horizontal bearings (A-A') to be flat and parallel.
2. Angular surfaces (B) and (C) to be equally inclined with respect to the horizontal bearings.
3. Angular surfaces (B) and (C) to be parallel.

PROCEDURE:

Surfaces (A-A')

The horizontal bearings (A-A') of the sliding member illustrated in Fig. 25.20 are spotted by employing a SURFACE PLATE and a STRAIGHT EDGE alternately. This portion of the procedure is similar to that explained in Sec. 25.1. The treatment of these surfaces is concluded upon realization of OBJECTIVE NO. 1.

Surface (B)

After determining the guided slide, assumed in this example to be dovetail side (B), turn the member to the position shown in Fig. 25.20. For situations like this a tilting turn-table (See Sec. 4.6) will be a convenient accessory. In order to keep dovetail side (B) at a constant angle with the horizontal surface (A), a dovetail TEMPLATE is required. The type shown in Fig. 25.16 is appropriate. Since the TEMPLATE will also be used on dovetail side (C) the construction time is well spent.

To maintain flatness and indicate bearing quality an ANGLE STRAIGHT EDGE should be applied alternately. It will facilitate stabilized markings if this tool is allowed to slide into the groove (D) which will help support the weight. Be sure to inspect the groove for clearance as recommended in Sec. 18.2. When a good bearing quality is established, denoting overall flatness, surface (B) is completed.

Surface (C)

Turn the member so that gib surface (C) assumes the same position vacated by surface (B). The spotting routine is performed with the same tools and in a manner similar to the one just discussed. Since we now have an alignment to execute, we must check periodically for parallelism.

To make the test referred to, an indicating jig should be built after the model

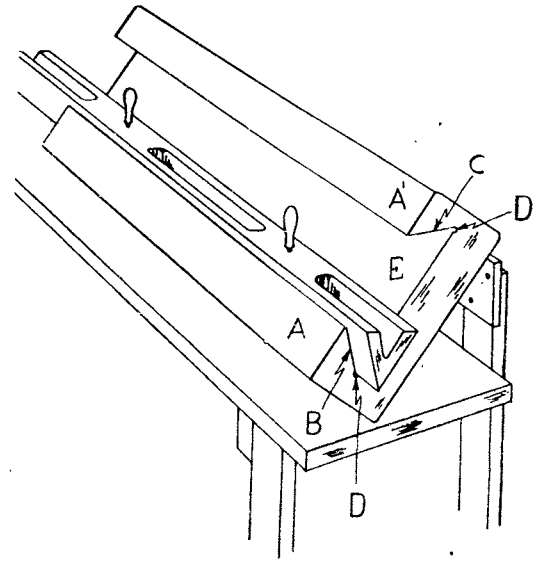

Fig. 25.20 Applying ANGLE STRAIGHT EDGE to female dovetail surfaces of casting tilted to facilitate spotting and scraping.

(A-A') flat surfaces (B-C) angular surfaces (D) groove (E) machined surface

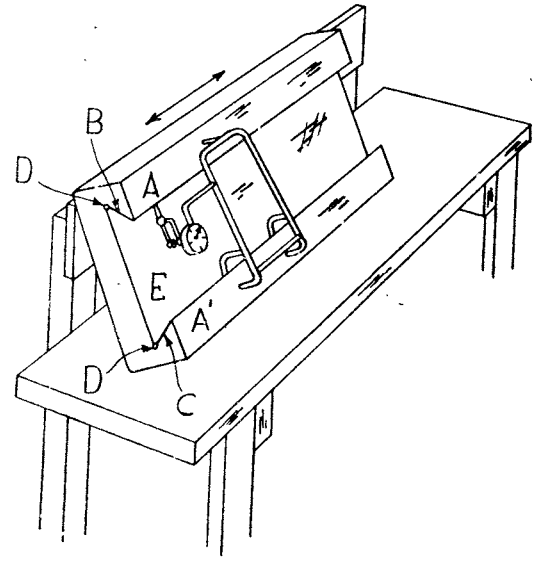

Fig. 25.21 Checking parallelism of female dovetail by means of INDICATING JIG and DIAL INDICATOR.

(A-A') flat surfaces (B-C) angular surfaces (D) groove (E) machined surfaces.

illustrated in Fig. 25.21. After attaching a DIAL INDICATOR, the apparatus is placed in contact against surfaces (A-A') and (C). The contact button is adjusted to

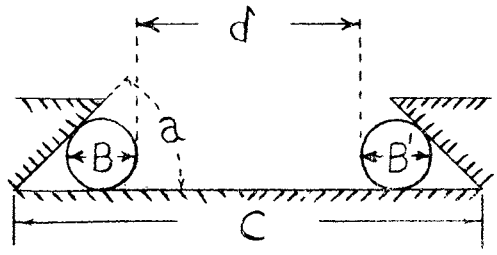

Fig. 25.22 Diagram of defective test for parallelism of dovetails.

(B-B') precision cylinders of identical diameter (C) machined surface (D) measurable distance

ride along surface (B). Then using the minimum of hand pressure the device is pushed from end to end of the member. Any tangible deviation from parallelism must be corrected by scraping surface (C) to achieve OBJECTIVE NO. 3.

Surface (E) is not a scraped surface. Consequently, it is not realistic to try and test for parallelism using two PRECISION CYLINDERS and an inside micrometer. The fallacy of such a system is brought out in the next section.

Sec. 25.13
Defective Test for Parallelism of Dovetails.

Some books dealing with subjects of interest to the machinist include a few paragraphs on the topic of "Measuring Dovetail Slides". The text usually explains how to measure the width of female dovetails and is often accompanied by an illustration similar to Fig. 25.22. In general machinist practice this is a qualified test, one so excellent in fact, that the scraping operator, who is also a machinist, must be warned against using it indiscriminately. This admonition is necessary because the test was designed for machining operations and not for scraping practice. With the former it is an efficient measurement because the accuracy demanded is not extreme. But for testing the precision scraping of machine members, it is too crude and should never be employed.

An examination of the accompanying Fig. 25.22 will disclose the reason for this. It will be seen that (B-B') represent precision ground cylinders, that (D) indicates the measurable distance, and that (C) denotes a machined surface. If this surface is not truly flat or has the slightest burr or high spot where the cylinders are set, one or the other, or both, of the test cylinders will be raised. Thus any measurement along (D) will be inaccurate.

It is permissible to use the test as illustrated to prove the parallelism of female dovetails, provided surface (C) is scraped flat and to a fine finish before placing the cylinders thereon for measuring. However, this machined surface (C) should never be scraped to a high finish for the solitary purpose of making a test. Female dovetails can be tested for parallelism far more speedily and accurately by adopting the recommendations outlined in Sec. 25.12.

Sec. 25.14
OBJECTIVES: Combination V surface and Flat surface

1. Flat bearing to be level, transversely and longitudinally.
2. Vee to be formed so that a vertical line line will bisect the angle. (No tilt)
3. Vee to be level in the longitudinal direction.
4. Vee and flat bearing to be parallel in vertical plane.

PROCEDURE:

Illustrated in Fig. 25.23 is a combination V and flat bearing which is a typical

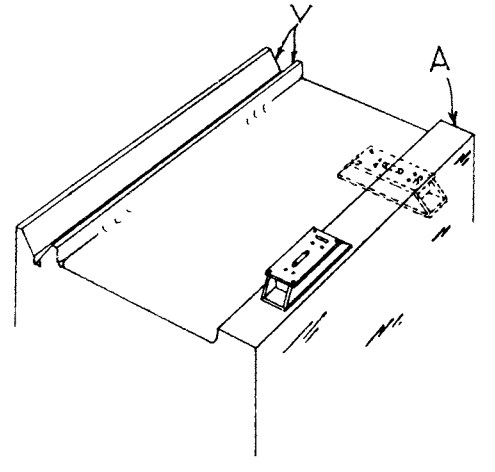

Fig. 25.23 Casting having combination V-way and flat way. Use PRECISION LEVEL to test flat way for levelness in two directions.

(A) flat way (V) sides of Vee.

machine design for bearing surfaces. These surfaces must be aligned to each other in a definite manner, as indicated by the several OBJECTIVES. In dealing with such a construction the bearings either may be dealt with jointly, or they may be treated separately. In the latter case, one surface is finished first and then the other is aligned to it. For the purposes of this discussion, we will adopt the latter arrangement. Incidentally, it must be assumed that in this and the following problems, the casting is first leveled satisfactorily.

Flat bearing (A)

Bearing (A) presents no special difficulty and may be spotted with either a SURFACE PLATE or a STRAIGHT EDGE, depending upon its size. It must be so scraped that a PRECISION LEVEL placed upon it, as shown in Fig. 25.23, will indicate dead level, thereby satisfying OBJECTIVE NO. 1. The flat bearing in some alignment procedures becomes the Datum Point for the V.

The V-Template

A very effective instrument in the treatment of the V-way is a V-TEMPLATE which must be made up to the required angle. The TEMPLATE fixes the angle between the sides of the Vee. For detailed instructions on making the gage refer to Sec. 12.10.

The V-Bearing

In treating these surfaces the TEMPLATE above mentioned and a STRAIGHT EDGE are applied alternately to spot the sides of the Vee. By this operation the

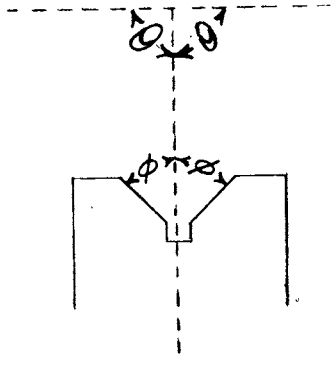

Fig. 25.24 Diagram showing the ideal form of V-way with a vertical line bisecting the V angle. Achieving this condition permits each side of the V to support an equal load.

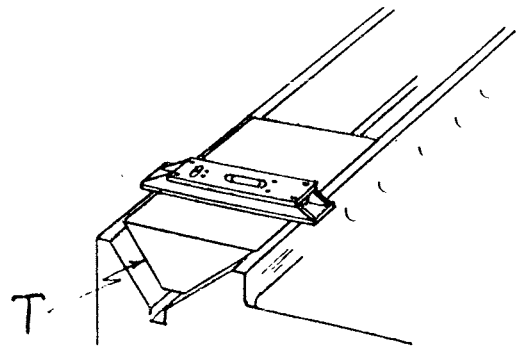

Fig. 25.25 Method of proving by means of a V-TEMPLATE and PRECISION LEVEL that V-way is bisected by an imaginary vertical line.

(T) Template

TEMPLATE determines the angle between the sides as represented in Fig. 25.24, and the STRAIGHT EDGE helps develop flatness.

To prevent the V from tilting, which in effect would cause one side to support more than its proportionate share of the weight of the sliding member, we must check frequently for OBJECTIVE NO. 2. To make the test the TEMPLATE is placed in the V and a PRECISION LEVEL is set on it as shown in Fig. 25.25. If the bubble in the glass vial centers, the OBJECTIVE is attained.

Simultaneously, a check is made for levelness in the longitudinal direction by turning the PRECISION LEVEL 90° to its former position. If the bubble again centers in the vial, OBJECTIVE NO. 3 is fully realized.

Another method of testing for levelness longitudinally is shown in Fig. 25.26. A cylindrical, precision ground test bar is inserted in the V and the LEVEL is held on top. If the position of the bubble is centered, the bearing is level longitudinally. Continue scraping on the V until this condition is achieved.

OBJECTIVE NO. 4 supplements OBJECTIVE NO. 3. In this case, the set up requires laying a cylindrical test bar in the V, as represented in Fig. 25.27. A Surface Gage with attached DIAL INDICATOR is placed on the flat bearing and readings are taken at both ends of the test bar, specifically at points (M) and (N). Identical readings indicate that the bearing surfaces are parallel in the vertical plane.

When the distance between the flat and the V is excessive, the extended arm holding the DIAL tends to overbalance the set up thereby impairing accuracy. A similar condition prevails when the flat way is quite narrow. The arrangement illustrated in Fig. 25.28 is devised to cope with either situation. Briefly, a cylindrical precision test bar is inserted in the Vee at one end of the member. A number of PRECISION GAGE BLOCKS are laid on the flat bearing at the same end. To complete the set up, a SCRAPED PARALLEL is placed across the two and a LEVEL is set on top of the PARALLEL. If the bubble in the glass does not center, PRECISION GAGE BLOCKS are added until it does. The apparatus is then moved intact to the other end of the member and checked again. If the bubble centers also at this end of the member, the V and flat are judged parallel as per OBJECTIVE NO. 4.

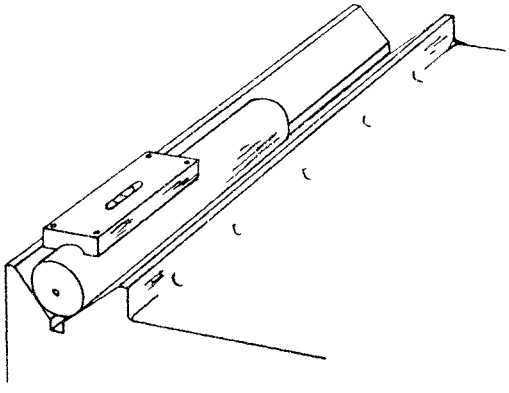

Fig. 25.26 Checking V-way for levelness by setting a PRECISION TEST BAR in Vee and laying a PRECISION LEVEL on top. Note groove in base of LEVEL.

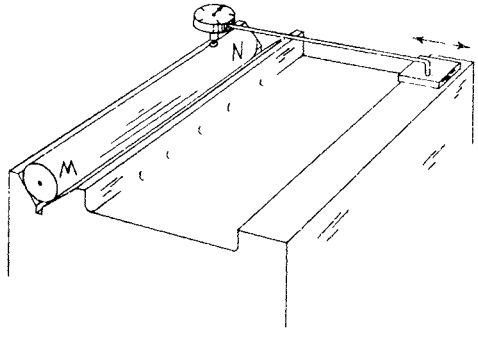

Fig. 25.27 Showing set up for testing parallelism of V-way to flat way over short distances. Precision Cylinder is placed in V and measurements made at (M) and (N) with DIAL INDICATOR attached to Surface Gage.

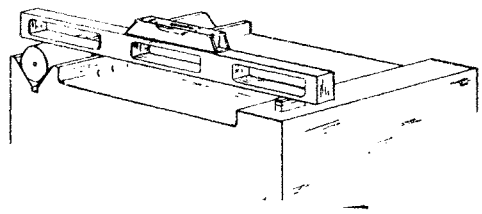

Fig. 25.28 Arrangement for testing V-way and flat way for parallelism when surfaces are widely separated. PRECISION LEVEL and PARALLEL are supported at one end by PRECISION CYLINDER in V and by PRECISION GAGE BLOCKS on flat way.

Sec. 25.15
OBJECTIVES: Double Vees

1. Vees to have equal angles.
2. Vees to be formed so that each will be bisected by a vertical line.
3. Vees to be level longitudinally.
4. Vees to be level transversely.
5. Vees to be parallel in horizontal plane.

PROCEDURE:

When dealing with a construction such as typified in Fig. 25.29, the horizon will be the most suitable Datum Point. Hence the PRECISION LEVEL will be the principal alignment tool.

Other essential equipment includes a specially made V-TEMPLATE. Such a gage made up with the required angle can be applied alternately with the STRAIGHT EDGE to attain OBJECTIVE NO. 1. The TEMPLATE used in combination with a PRECISION LEVEL determines OBJECTIVE NO. 2 also. The procedure is the same as described in the previous problem, Sec. 25.14.

While the spotting and scraping is carried on, checks for levelness and parallelism are repeatedly made as follows:

Cylindrical precision test bars are placed successively in the Vees in four locations, viz: at both ends of the two Vees. In each position a reading is taken from a PRECISION LEVEL held on top. If the bubble in the glass vial centers every time, the Vees are considered level

in the longitudinal direction. Fig. 25.29 illustrates the test for OBJECTIVE NO. 3.

The set up for testing OBJECTIVE NO. 4 is shown in Fig. 25.30. Two precision ground cylindrical test bars of equal diameter are required. One test bar is placed in each Vee at, say, the near end. A PARALLEL is bridged across the bars as shown. Then a PRECISION LEVEL is set on top of the PARALLEL, and the position of the bubble is noted. Next the appartaus is moved to the other end of the Vees. Here another reading is taken. If the bubble centers at both ends of the member the Vees are level transversely.

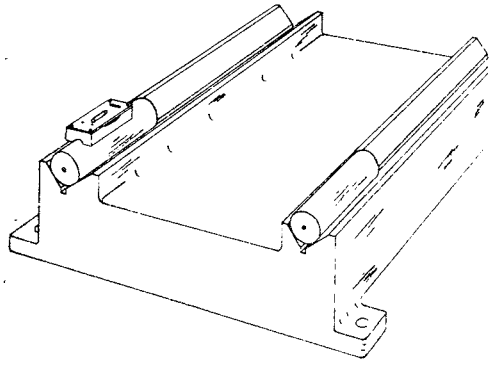

Fig. 25.29 Method of checking levelness of Double Vees using Cylinders and PRECISION LEVEL. Note groove in base of LEVEL.

To verify the parallelism of the two Vees proceed as follows: A type of dummy spindle test bar, such as is mentioned in Sec. 15.3, is inserted in a Vee at one end. A DIAL INDICATOR is fastened to an arm clamped to the rotor of the device, as represented in Fig. 25.31. In the other Vee is set a cylindrical precision test bar of any suitable size. The DIAL INDICATOR is adjusted so that, as it is oscillated up and down, it will make contact with the test bar. The maximum reading is noted whereupon the face of the DIAL is "zeroed" to that calibration. Then without altering the setting of the instrument, the set up is transferred to the other end of the Vees where the check is repeated. If an identical reading is observed in both locations, the two Vees are parallel as required by OBJECTIVE NO. 5.

The set up employing a dummy spindle test bar, is preferred for testing this

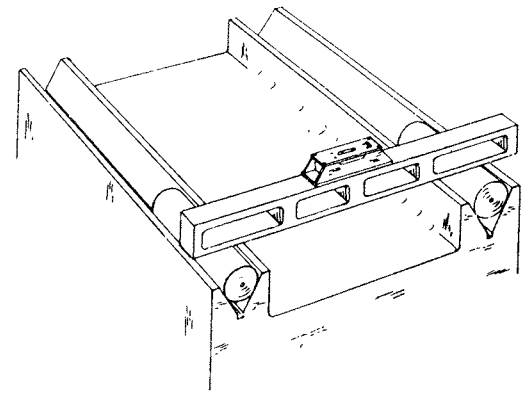

Fig. 25.30 Checking levelness of double Vees in the transverse direction. PARALLEL is used to span the distance separating CYLINDERS.

alignment because it is a fast method. This is a decisive advantage because the test for parallelism is one frequently made during the scraping operations on double Vees. By using this test much time can be saved. However, should this special apparatus not be available, an equally exact though slower procedure employing standard equipment can be adopted as follows:

A PRECISION CYLINDER of any random diameter is laid in each Vee. Measurements are made between the cylinders at both ends of the member with an inside micrometer. Calibrations must be identical to denote parallelism.

Another suitable system is to attach a DIAL INDICATOR to one of the PRECISION CYLINDERS, adjusting the plunger button to bear against the second CYLINDER. Accurate readings can be obtained if the test bar holding the DIAL INDICATOR is oscillated smoothly.

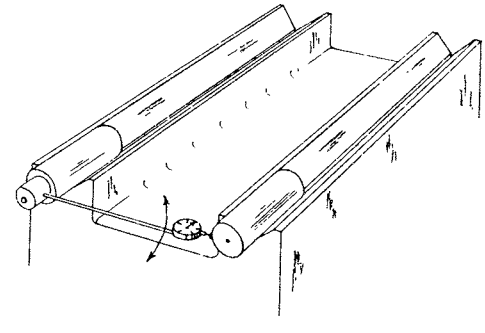

Fig. 25.31 Testing parallelism of Double Vees in horizontal plane. DIAL INDICATOR is fastened to a Dummy spindle Test Bar.

Sec. 25.16

OBJECTIVES: Combination Inverted V surface & Flat surface

1. Flat bearing to be level, transversely and longitudinally.
2. Inverted V to be formed so that a vertical line will bisect the angle.
3. Inverted V to be level in the longitudinal direction.
4. Inverted V and flat bearing to be parallel in the vertical plane.

PROCEDURE:

The construction of this form of bearing member is illustrated in Fig. 25.32. The flat bearing being easiest to treat is chosen as the Check Point and is, therefore, dealt with first.

In most cases a STRAIGHT EDGE is selected as a spotting tool. However, if the flat way is rather wide it may be advisable to make alternate applications of compound with a SURFACE PLATE.

As the scraping operation proceeds, a PRECISION LEVEL is placed on the flat, again referring to Fig. 25.32. Checks for levelness are made in both the transverse and longitudinal directions. When the bubble in the glass centers in all positions where the instrument is set, the flat bearing is leveled, and OBJECTIVE NO. 1 is satisfied.

We turn now to the other surface but before the inverted V can be treated it is essential to have an inverted V-TEMPLATE made up to the angle desired. (For methods of producing such a gage refer to Sec. 12.13.) Assuming that the TEMPLATE has been prepared, it is used to spot the sides of the inverted V. To prevent a "wind" from developing in this surface, it is advisable to alternate the TEMPLATE with the STRAIGHT EDGE while spotting. Thus the one tool indicates the proper angle while the other tool registers flatness and straightness.

The surface should also be tested at frequent intervals for tilt. To perform this operation the TEMPLATE is laid on the inverted V and a PRECISION LEVEL is positioned cross-wise, as shown in Fig. 25.33. The bubble must center if OBJECTIVE NO. 2 is to be realized. By the simple expedient of turning the level 90° we can test for OBJECTIVE NO. 3, which is indicated in the same fashion.

A check for OBJECTIVE NO. 4 is prepared in the following manner. The TEMPLATE is laid on the inverted V at one end and a cylindrical precision test bar is placed on top, as shown in Fig. 25.34. A DIAL INDICATOR mounted on a suitable stand is set on the flat bearing. The device is moved transversely across the flat while the DIAL button contacts the top of the test bar. After noting the maximum reading on the instrument, the setup is transferred to the other end of the member where the process is repeated. The two readings must be identical before OBJECTIVE NO. 4 is satisfied.

When the distance between the inverted V and the flat cannot be spanned conveniently with a DIAL INDICATOR and stand, the arrangement shown in Fig. 25.35 may be adopted. In this test PRECISION GAGE BLOCKS are used to support one

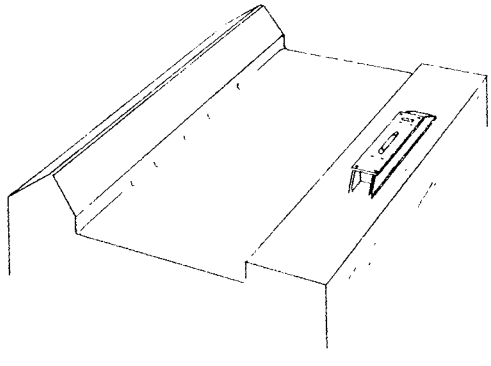

Fig. 25.32 Checking levelness of flat way of combination inverted V and flat surface.

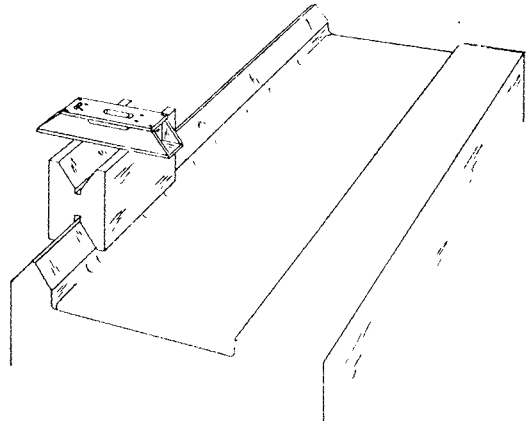

Fig. 25.33 Checking inverted V surface for tilt by interposing gage under LEVEL.

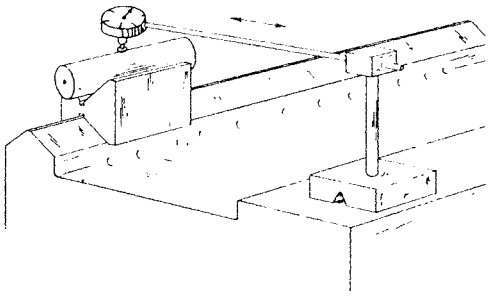

Fig. 25.34 Method suitable for spanning short distances when checking parallelism of inverted V and flat way. Use inverted V-gage and PRECISION CYLINDER to provide accurate test surface for DIAL INDICATOR.

end of the SCRAPED PARALLEL while the other end rests on a cylindrical test bar inserted in the TEMPLATE. The GAGE BLOCKS are built up until the bubble in the LEVEL is centered. Next the apparatus is moved intact to the other end of the bearing surfaces. The bubble must center at this end also before OBJECTIVE NO. 4 is achieved.

OBJECTIVES NO. 2, NO. 3, and NO. 4 must be concluded simultaneously.

Sec. 25.17

OBJECTIVES: Double Inverted Vees.

1. Inverted Vees to have equal angles.
2. Inverted Vees to be formed so that a vertical line will bisect the angle.

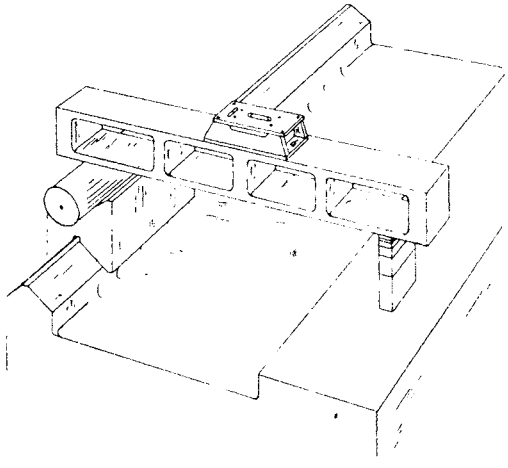

Fig. 25.35 Checking parallelism of inverted V and flat way by method suitable for extended distances. PARALLEL and LEVEL are supported by the inverted V-gage and CYLINDER at one end and by GAGE BLOCKS at the other.

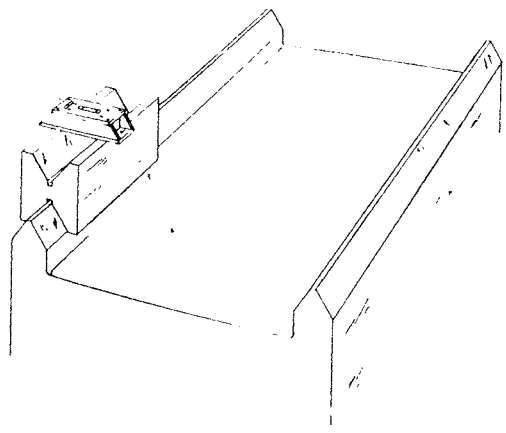

Fig. 25.36 "Test for Tilt." Method of proving double inverted Vees are so formed that a vertical line will bisect the V. Set inverted V-gage at several positions in succession on first one bearing then on the other.

3. Inverted Vees to be level longitudinally.
4. Inverted Vees to be parallel in vertical plane.
5. Inverted Vees to be parallel in horizontal plane.

PROCEDURE:

To deal with bearing surfaces such as these, special tools are necessary. The principal need is for two identical inverted V-TEMPLATES having the required angle. (Details of construction are provided in Sec. 12.13) The TEMPLATES are employed for spotting purposes to develop the angle specified in OBJECTIVE NO. 1. They are also needed in carrying out the various alignment tests. Alternate applications of a STRAIGHT EDGE should be made to the surfaces in question to promote flatness and straightness and indicate the surface bearing quality.

The spotting and scraping operations attendant to this work cannot be carried on without repeated tests to satisfy the other requirements. For example, to prevent tilting the bearings being scraped the following set up should be made:

Place a TEMPLATE at the end of one inverted V and set a PRECISION LEVEL cross-wise on top of it, as represented in Fig. 25.36. Do this at various locations and then repeat on the other inverted V. The bubble in the glass must center at all positions to fulfill OBJECTIVE NO. 2.

At the same time the inverted Vees should be examined for levelness longi-

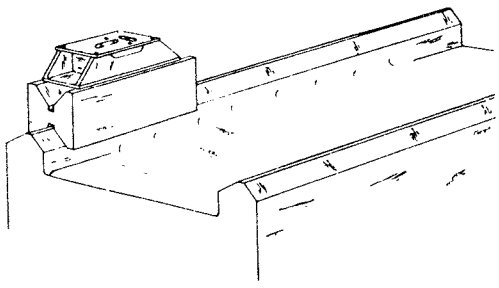

Fig. 25.37 Testing double inverted Vees for levelness in longitudinal direction. Interpose gage between bearing sides and LEVEL.

tudinally, as illustrated in Fig. 25.37. Here again the surfaces should be tested at several positions so that the accuracy demanded in OBJECTIVE NO. 3 may be realized. It should be remembered that we are concerned at present only with the problem of making the bearing surfaces level. The current problem has no connection with the routine of leveling the casting from the leveling surfaces. That altogether different subject was discussed at length in Sec. 14.8 and Sec. 14.14.

We check for parallelism in the vertical plane as shown in Fig. 25.38. The equipment employed consists of the two identical TEMPLATES, two PRECISION GROUND TEST BARS of equal diameter, a PRECISION SCRAPED PARALLEL, and a PRECISION LEVEL. The set-up is made successively at one and then the other end of the member. The bubble in the vial must occupy the same position in both instances to indicate that OBJECTIVE NO. 4 is accomplished.

Any deviation from parallelism in the horizontal plane between the two Vees can be measured by utilizing the arrangement shown in Fig. 25.39. This shows a TEMPLATE placed on each inverted V, and a CYLINDRICAL PRECISION TEST BAR of appropriate size inserted in one TEMPLATE. In the other TEMPLATE is laid a dummy spindle test bar. To the rotor of this test bar is attached a rod of suitable length. Fastened to the end of the rod is a DIAL INDICATOR. The latter instrument is adjusted so that as the rotor is oscillated up and down, contact is made between the button and the cylindrical precision test bar. When the maximum reading is noted, the DIAL is "zeroed" to that reading. Then the apparatus is moved to the other end of the member where the test is repeated. A zero-zero reading must be observed before OBJECTIVE NO. 5 is realized.

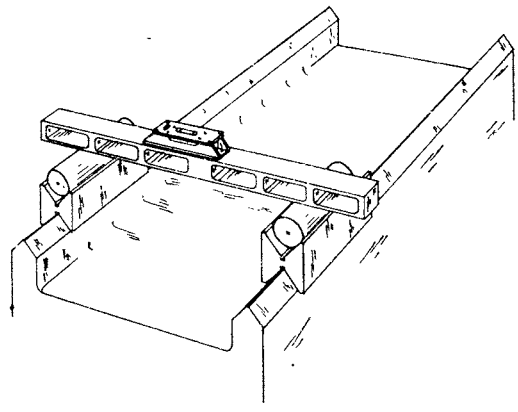

Fig. 25.38 Checking double inverted Vees for parallelism in vertical plane. PARALLEL is used to span distance.

A cylindrical test bar may be substituted for the dummy spindle test bar mentioned above. If this is done, make sure that the test bar turns smoothly in the V of the TEMPLATE.

Although the distance between the two cylindrical test bars could be checked with an inside micrometer, the arrangements just described are preferable because of the rapidity with which the test can be conducted.

NOTE:

To obtain accurate measurements the TEMPLATES must be firmly seated on the inverted Vees. The wider the

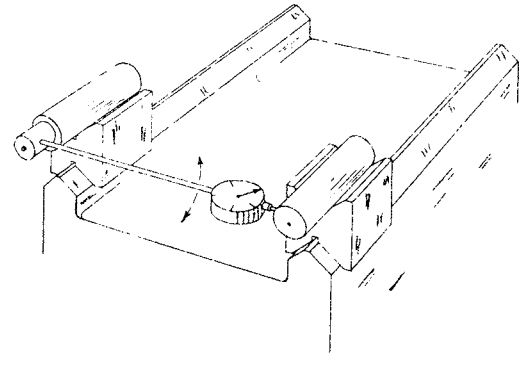

Fig. 25.39 Method of testing double inverted Vees for parallelism in horizontal plane. DIAL INDICATOR is attached to Dummy Spindle Test Bar.

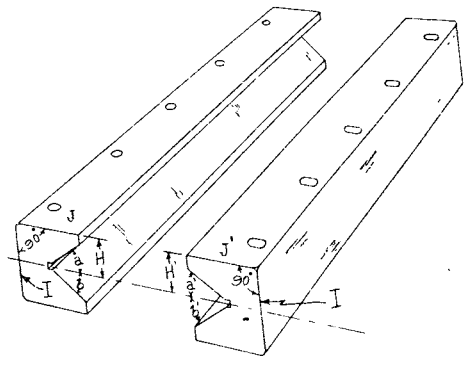

Fig. 25.40 Showing a pair of V guides or Ram guides.

(J-J') surfaces bolting against rear of main casting (1) surface bolting against side of main casting - non-adjustable (I') surface which contacts adjusting screws - adjustable to provide clearance for ram (ab-a'b') Vee angle (H-H') critical distance from J-J' to line bisecting angles.

sloping sides of the Vees the more stable is the arrangement.

Sec. 25.18

Single V guides are separate, removable sections often used in Punch Presses. They act as guides for the opposed V slide, or ram, which is discussed in the next problem. When prepared for this usage they must be dealt with in pairs. Fig. 25.40 shows the two ram guides with the various critical surfaces and angles lettered for identification.

The alert reader might question the need for so extensive a series of OBJECTIVES as is given below. It must be remembered, however, that we would not treat the ram guides without also treating the ram. In order to expedite the latter operation we use the V guides as templates and, therefore, must necessarily be more exacting in our requirements.

OBJECTIVES: V guides or Ram guides.

1. The angles of the Vees to be identical. (Thus angle ab to equal angle a'b')
2. A straight line square with surfaces (I-I') to bisect the V angles. (Thus angle a to equal angle b and angle a' to equal angle b')
3. Vees to be parallel to (I-I').
4. Surfaces (J-J') to be square with surfaces (I-I').
5. Vees to be parallel to (J-J').
6. Measurements (H-H') to be equal.

PROCEDURE:

The initial surfaces treated should be the angular sides of the Vee in each guide section. These are the most difficult parts to scrape and should be done first because perfecting the various alignments can be accomplished more easily by scraping the flat surfaces.

In order to spot the Vee, maintain equal angles, and conduct alignment tests it will be necessary to provide a suitable V-Template. Since it would be repetitious to describe again how to construct such a device, the reader is referred to Sec. 12.10 where the method is fully discussed.

The Vee in each guide is now spotted, alternating between the above mentioned Template and an ANGLE STRAIGHT EDGE. Scraping is continued until the V angle in each guide is identical, as required by OBJECTIVE NO. 1, and has an adequate surface bearing quality. So much for the preliminaries, we come now to the alignment testing.

The next surfaces that should be dealt with are (I-I'). A SURFACE PLATE or STRAIGHT EDGE will spot these surfaces efficiently. In scraping them the proper alignment must be maintained with the V. This involves two OBJECTIVES, namely, NO. 2 and NO. 3. The operator would be

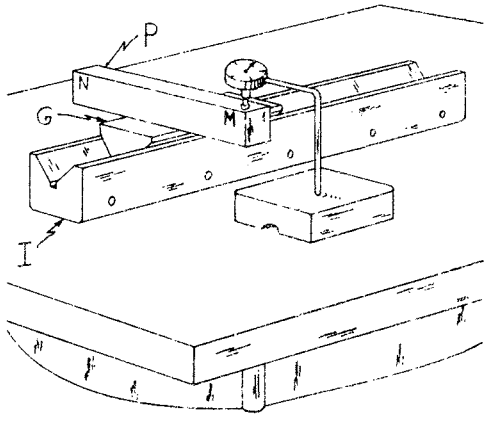

Fig. 25.41 Set up for testing ram guide to determine if a line perpendicular to surface (I) will bisect the V angle. Repeat test on (I'). Measurements are made with a DIAL INDICATOR from SURFACE PLATE to both ends (M) and (N) of PARALLEL set on V-gage.

(P) Parallel (I) surface of ram guide (G) V-gage

well advised to perform the tests for both alignments repeatedly and consecutively, as this saves much time and effort.

The test for OBJECTIVE NO. 2 is represented in Fig. 25.41. The guide member is placed on a SURFACE PLATE as shown. The V-TEMPLATE is inserted in the V and a PARALLEL is laid crosswise. A DIAL INDICATOR, connected to a Surface Gage, is adjusted to touch one end of the PARALLEL, for example, at (M) where a reading is taken. Without changing the setting of the INDICATOR, a similar check is made at (N). A zero-zero reading between points (M) and (N) is required. Both guides are tested in the same fashion. If the necessary accuracy is not evident, scrape surfaces (I-I') until OBJECTIVE NO. 2 is fulfilled. There is no obligation that the distance from the top of the PARALLEL to the SURFACE PLATE be the same on both guides.

The test for OBJECTIVE NO. 3 is illustrated in Fig. 25.42. The reading of the DIAL INDICATOR between (P) and (Q) must be zero-zero. Both guides are thus tested. The height or distance from the top of the test bar to the SURFACE PLATE is not important and may be different for each guide. This condition is the same as noted in the previous OBJECTIVE. Scrape (I-I') until OBJECTIVES NO. 2 and NO. 3 are attained simultaneously.

Next surfaces (J-J') are treated. Since three alignments are involved, tests must be made consecutively for OBJECTIVES NO. 4, NO. 5, and NO. 6. Any correction required is made on surfaces (J-J').

To expedite the work a RIGHT ANGLE TEMPLATE is made up and used to insure the fulfillment of OBJECTIVE NO. 4. The SURFACE PLATE is applied alternately with the TEMPLATE.

Scraping of surfaces (J-J') should be co-ordinated with tests to determine progress in the alignments specified by OBJECTIVES NO. 5 and NO. 6. One set up will suffice for both. Place first one guide, then the other, on the SURFACE PLATE with sides (J-J') in contact. Hold a PRECISION CYLINDER in the V and measure with a DIAL INDICATOR as shown in Fig. 25.43. A zero-zero reading must be secured at (R-S) in order to realize OBJECTIVE NO. 6. Furthermore, and this is important, the readings must

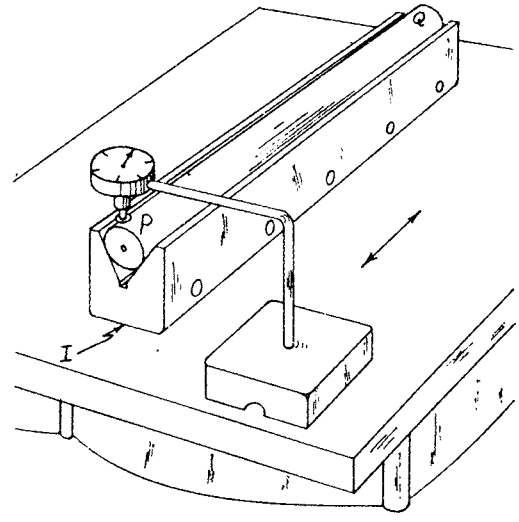

Fig. 25.42 Method of testing whether the axes of the Vees are parallel to surface (I) and surface (I'). Insert PRECISION CYLINDER in Vee and make measurements at (P) and (Q) with a DIAL INDICATOR.

be identical for (R'-S'). Only thus can (H) equal (H') satisfying OBJECTIVE NO. 6. To assure maximum accuracy in this matter do not alter the setting of the DIAL instrument and be sure to use the same PRECISION CYLINDER in both Vees. Both guides are judged completed only after all OBJECTIVES are fulfilled.

Sec. 25.19

The following type of construction, illustrated in Fig. 25.44, is called a ram

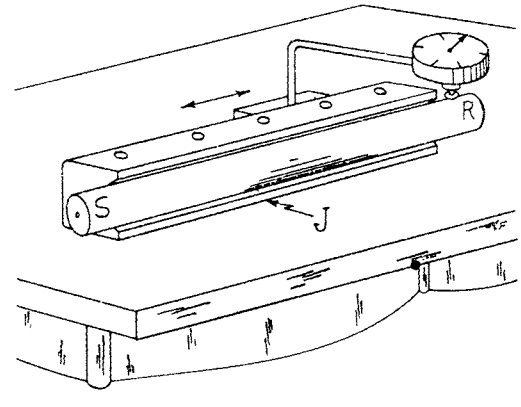

Fig. 25.43 Testing axis of V for parallelism with reference to surface (J). Measurements taken at (R-S) must be zero-zero and must be identical with those taken at (R'-S'). Thus (H-H') are equal.

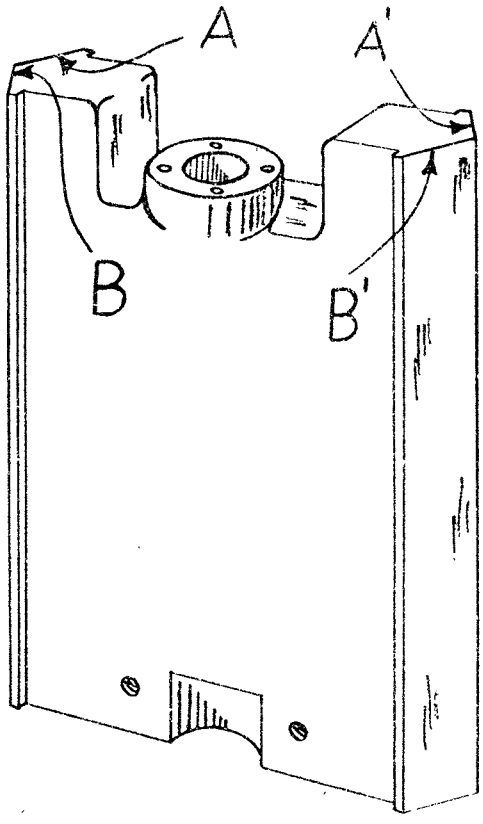

Fig. 25.44 Ram or slide of punch press or similar machine illustrating form of horizontal opposed inverted V-ways.

(A-B) Angular sides of inverted V (A'-B') angular sides of inverted V.

or slide. Its position and direction of movement in a machine assembly are directed by the guides described in the previous problem.

OBJECTIVES: Horizontal Opposed Inverted Vees.

1. Opposed inverted Vees to have equal angles. (Thus angle ab to equal angle a'b')
2. Opposed inverted Vees to be formed so that a straight line will bisect both V angles. (Thus angle a is equal to angle b; and angle a' is equal to angle b')
3. Opposed inverted Vees to be parallel.

PROCEDURE:

The preferred method of scraping and aligning a machine part having horizontal opposed inverted Vees is to start with accurate spotting templates. These would be the ram guides discussed previously in Sec. 25.18. The guides mentioned are applied alternately with a STRAIGHT EDGE to spot the bearing surfaces (A-B) and (A'-B') seen in Fig. 25.45. The proper application of these tools combined with accurate scraping will automatically generate the equal angles (ab and a'b') on each inverted V and will fulfill the conditions of OBJECTIVE NO. 1.

To achieve OBJECTIVE NO. 2, more is required than that both angles (ab) and (a'b') be equal as specified in the first OBJECTIVE. Additionally, they must be aligned so that both V angles can be bisected by a straight line passing through the member. This is a more important consideration than the preceding one, if the ram and ram guides are to fit when assembled without resort to makeshift shimming, which is seldom completely satisfactory and not to be recommended.

Fig. 25.46 illustrates how to prove whether this condition exists. The machine member is laid on top of blocks placed on a SURFACE PLATE. The two V-guides are clamped to the member with sides (J-J') on top, as shown. (This is the position they will occupy in relation to each other and to the ram when installed in the machine.) Now if the scrape-

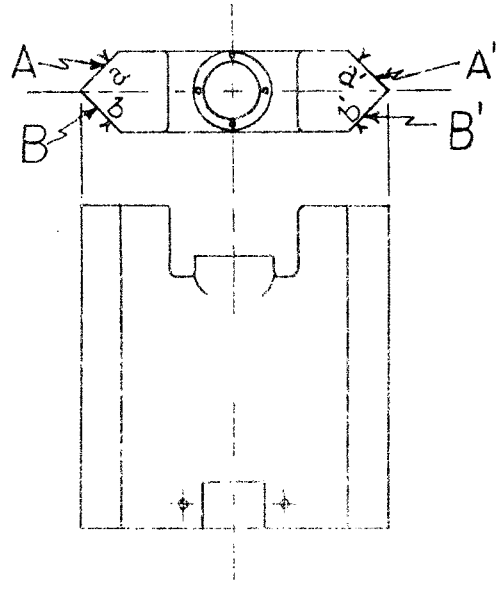

Fig. 25.45 Machine drawing of opposed inverted V-ways.

(A-B) Bearing surfaces to be scraped (A'-B') bearing surfaces to be scraped (ab) equal angles (a'b') equal angles.

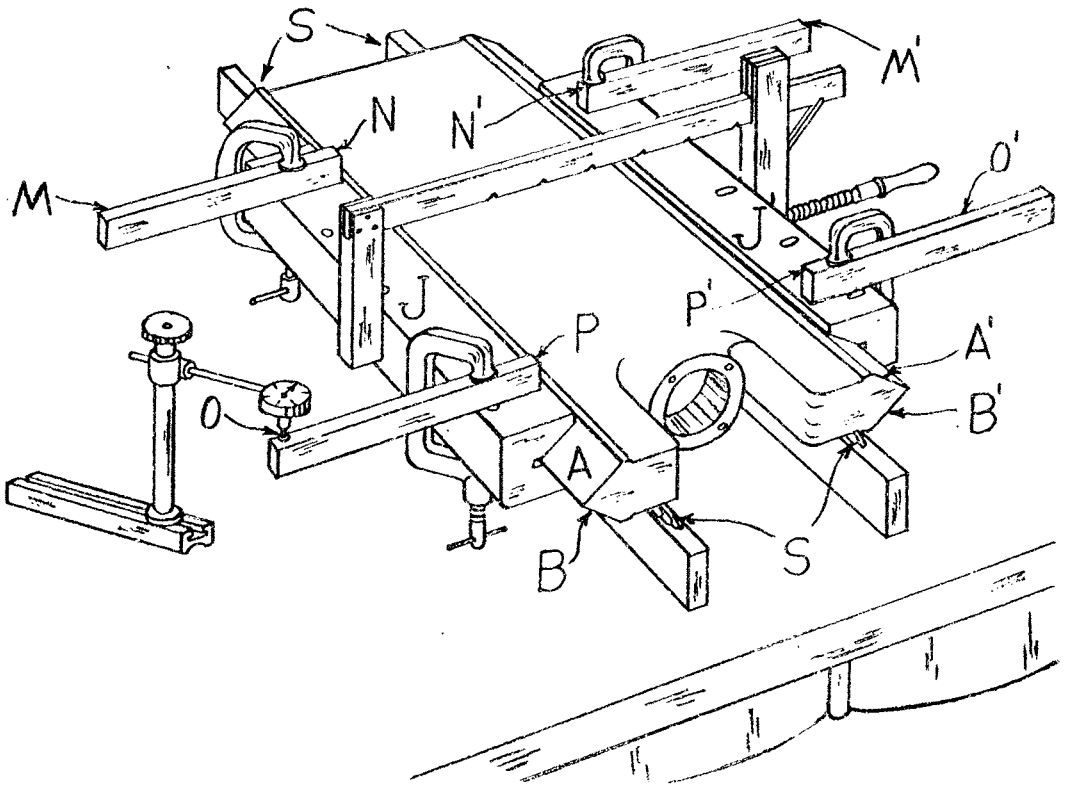

Fig. 25.46 Set up for proving that a straight line will bisect the inverted Vee angles.

(M, N, O and P) End positions on two PARALLELS (M', N', O' and P' end positions on two PARALLELS (s) shims (AB - A'B') opposed inverted V bearing surfaces.

finished surfaces (J-J') are parallel with, and equi-distant from the DATUM PLANE, OBJECTIVE NO. 2 is realized.

This is proved one way or the other as follows: Four matched PARALLELS are obtained. Two are fastened with clamps to the V-guide on surface (J). The other pair are clamped to the V-guide against surface (J'). A Surface Gage with attached DIAL INDICATOR is brought into play and measurements are made at points (M-N) and (O-P) on the PARALLELS secured to (J), as shown. The ram is shimmed until a DIAL reading of zero-zero is had at all four points. Then without disturbing the setting of the instrument, we perform the balance of the test on the other two PARALLELS.

Referring again to Fig. 25.46, take measurements at (M'-N') and (O'-P'). If the tests show readings identical with those obtained at (M-N) and (O-P), the slides of the ram member are satisfactorily aligned. In other words, the readings must not only be zero-zero, they must also be identical on all four PARALLELS, i.e. at eight points of measurement. In case the readings taken along (M'-N') and (O'-P') are not similar, then both surfaces (A-B) and (A'-B') must be worked jointly, as before, until the requisite conditions (OBJECTIVE NO. 2) are fulfilled.

In Fig. 25.47 is shown the check to determine whether the opposed inverted Vees have divergence in the longitudinal direction. Place one guide on a SURFACE PLATE as in the figure. Seat the ram in the guide. (There will be no danger of it toppling.) Lay the other guide on top of the ram. Use a Surface Gage with attached DIAL INDICATOR, to take measurements at points (S) and (T) on the upper guide. If a zero-zero reading is

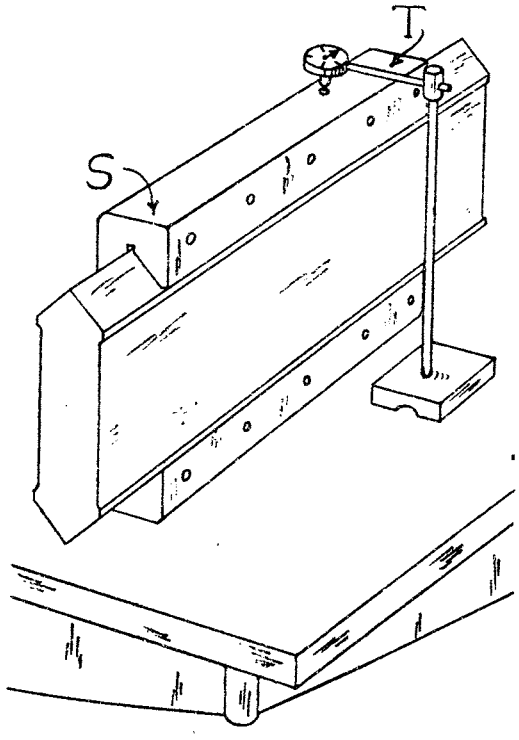

Fig. 25.47 Arrangement for testing parallelism of axis of one opposed inverted V with the other.

(S-T) Measuring points on ram guide.

indicated, the opposed inverted Vees of the ram member do not diverge and are in fact parallel as required by OBJECTIVE NO. 3.

The operation of aligning the ram slides, consisting of four surfaces (A-B) and (A'-B'), is executed successfully only when all OBJECTIVES are attained simultaneously.

Sec. 25.20

OBJECTIVES: Combination Angular and Flat bearings.

1. Flat bearing to be level longitudinally and transversely.
2. Slope of angular surfaces to be similar.
3. Angular surfaces to be parallel.

PROCEDURE:

The construction under discussion is illustrated in Fig. 25.48. In dealing with it, the flat way (a) is selected as the Check Point and therefore is treated first. A STRAIGHT EDGE and a SURFACE PLATE are used alternately to spot this surface. Scraping is continued until a PRECISION LEVEL placed on the bearing surface indicates that it is level in both directions as required by OBJECTIVE NO. 1. The prescribed surface bearing quality must also be produced at this time. This completes the flat bearing (a).

The angular bearings (b-c) are easily spotted with a STRAIGHT EDGE. This tool will help maintain over-all flatness. At the same time a correctly designed OBTUSE ANGLE TEMPLATE is applied to each surface, laying it from the flat bearing (a), as shown in Fig. 25.48. (While this is done the DIAL INDICATOR is temporarily detached.) This spotting procedure, in conjunction with careful scraping, will develop an equal slope on each angular surface thereby satisfying OBJECTIVE NO. 2.

OBJECTIVE NO. 3 is attained when the DIAL INDICATOR, attached to the above mentioned TEMPLATE, indicates a zero-zero reading from end to end of the casting.

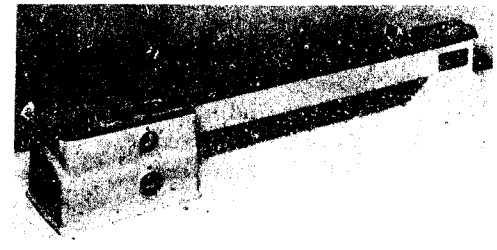

PLATE 18. View of bed casting of lathe having angular ways and flat way. A T-slot is provided for clamping the headstock and tailstock to the bed ways. (Courtesy - Elgin Tool Works.)

The combination angular and flat bearings just described may be found, for example, on the beds of various makes of tool maker's bench lathes. This type of bearing surface is relatively easy to scrape and is included here only as an introduction for the more difficult procedure involved in scraping the sliding members which have contact with it. In other words, the discussion of this bearing surface would be incomplete without explaining also the procedure of scraping a typical member to fit it.

We will, therefore, use as an example the tailstock of the lathe. Basically,

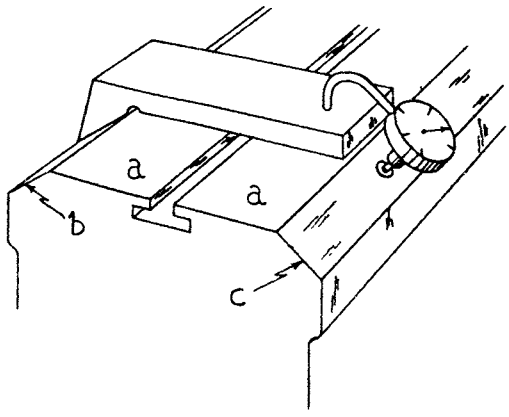

Fig. 25.48 Method of maintaining correct angle by means of OBTUSE ANGLE TEMPLATE. Attached DIAL INDICATOR is used to indicate parallelism.

(a) flat way (b-c) angular ways.

there is no difference between scraping a tailstock than a headstock. The tailstock must be aligned with the ways of the bed and the axis of its spindle must be aligned with the axis of the spindle of the headstock, and vice versa. Either member may be taken up first, but with this type of problem it is good practice to give priority to the headstock member, primarily because it is larger and heavier, hence less easily handled.

The headstock must be scraped so that the center-line of its spindle is somewhat lower than the present elevation of the

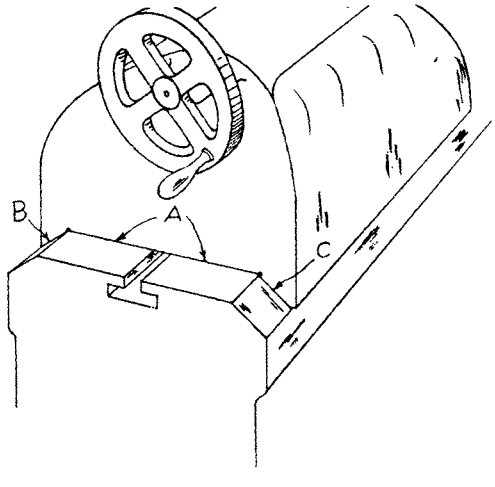

Fig. 25.49 Showing tailstock mounted on Bed having combination angular and flat bearings.

(A) flat slide of tailstock (B-C) angular slides of tailstock.

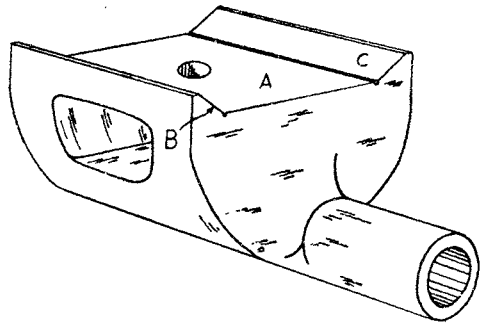

Fig. 25.50 Underneath view of bearing surfaces of tailstock.

(A) flat slide (B-C) angular slides.

tailstock axis (i.e. before scraping). This is required so that there will be sufficient surplus metal available on the tailstock to rectify its possibly inaccurate alignment, and to provide adequate bearing quality. Obviously, if the tailstock is badly deteriorated, more metal must be removed. Consequently, discrimination must be exercised in determining how much to lower the center-line of the headstock.

We will assume that the headstock has previously been scraped so that it is correctly aligned with the bed and that sufficient metal has been removed to lower the center-line of its axis below the center-line of the tailstock axis. The problem now is to scrape the tailstock to correct alignment.

Sec. 25.21
OBJECTIVES: Tailstock Alignment.

1. Axis of tailstock spindle to be aligned with the ways of bed in both the vertical and horizontal planes, and be in-line with the axis of the spindle of the headstock.

PROCEDURE:

The process of fitting the base of the tailstock requires the use, as a spotting template, of the bed, shown in Fig. 25.49. The method of scraping the tailstock is quite simple. The difficulty arises in accomplishing simultaneously, the necessary alignments and at the same time attaining an adequate bearing quality on the three surfaces of the tailstock base, namely (A), (B), and (C) of Fig. 25.50.

Extreme care must be exercised to remove just the right amount of metal

from each of the three bearing surfaces. They must be worked in as a unit, otherwise the scraper will find that, while the flat slide has good bearing, the angular slides may not, or vice versa. At the same time the problem is made more formidable due to the necessity of aligning the tailstock spindle with the bed ways in both the vertical and horizontal planes. Multiplying still further the scraper's difficulty is the fact that he must secure the correct bearing quality on three surfaces and produce perfect alignment of the tailstock spindle with the bed surfaces at the precise moment the axes of the two spindles are in-line.

By this time, if not before, the operator will comprehend the inherent complexities connected with this type of bearing surface. Should the center-line of the tailstock spindle be scraped lower than the center-line of the headstock spindle before the bearing quality of all three surfaces is adequate, or before the tailstock spindle is properly aligned, then the base of the headstock must be rescraped to modify it to the lowered center-line of the tailstock. This obviously involves duplication of effort but it is unavoidable. It is apparent, therefore, that while the combination angular and flat bearings discussed in the preceding problem (Sec. 25.20) are readily scraped, the major obstacle is encountered when mateing members are fitted thereto.

Chapter 26

THE ENGINE LATHE

The lathe is often called the "King of all tools". It owes this distinction to its versatility. With suitable attachments, more operations can be performed by the lathe than with a score of other tools. In addition, it can perform some operations not possible with other machines.

The lathe is made in numerous types and designs, no two of which are exactly the same. There are many differences in motive power, gearing, turning speed, controls, mounting, feed gear mechanisms, kind of service, degree of accuracy etc. All lathes, however, operate on the same principle. Therefore, if the treatment proposed here for the various members and surfaces is thoroughly understood, and the procedures which are based on practical experience are adopted, the scraping operator will have little difficulty in treating any lathe.

In the following pages, a lathe of elementary form, but having the maximum number of features and points of interest to the scraper, will be described.

Sec. 26.1
Components

The lathe is composed of a multiplicity of parts, most of which do not concern the scraper. There are only five principal members of a lathe which are directly involved in scraping operations. Fig. 26.1 shows the several members completely assembled. They are described briefly as follows:

1. The Bed.

This is a rectangular, open, box-like casting, usually of cast iron, or semi-steel, which is connected at intervals by reinforcing ribs. It is the foundation or frame-work for the parts which are attached to or slide upon it.

2. The Head Stock.

The head stock member occupies a fixed position on the bed. An integral part of the head stock is the rotating spindle which drives the work piece on a live center or holds it in a chuck.

3. The Tail Stock

This member is movable longitudinally along the ways of the bed and has provision for transverse adjustment. It supports a spindle or ram which anchors the dead center.

4. The Carriage.

The carriage is movable along the ways of the bed. It carries the compound slide rest on top, and the apron on the front side.

5. The Compound Slide Rest

This is an assembly of small members which provides a transverse or angular feed to the cutting tool.

Sec. 26.2
Sequence of Operations

Determining in what sequence these components shall be dealt with is our initial problem. Many experienced operators favor working on the five principal members in the order enumerated below, viz:

1. Level the bed. (See Sec. 26.35 through Sec. 26.39)
2. Scrape and align compound slide rest assembly.
3. Scrape and align the carriage.
4. Prepare slides of tail stock as a template
5. Scrape and align ways of bed.
6. Align the tail stock
7. Align the head stock
8. Final alignment of carriage

This particular sequence is chosen because it is one which yields adequate results in the minimum of time. Its principal

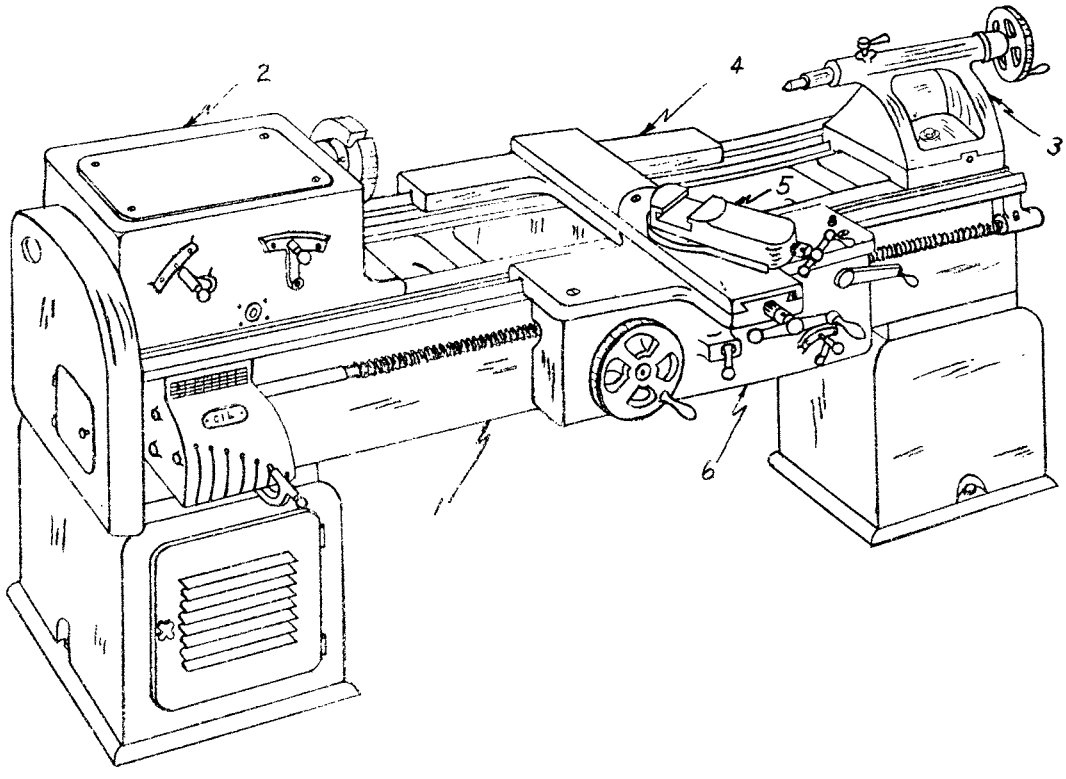

Fig. 26.1 View of the principal parts of the lathe
(1) bed (2) head stock (3) tailstock (4) carriage
(5) compound slide rest (6) apron

advantage is that by utilizing the lathe members themselves it avoids the necessity of making up many special TEMPLATES. The routine here adopted permits a member to serve as a spotting template for other uncompleted members. Individual preferences, or special circumstances, may be reason to modify this procedure somewhat but this is a matter for the experienced operator to decide. The reader may be certain, however, that the scraping order, as given above, is entirely practical and conducive to a high rate of efficiency.

An alternative plan of operations would be to prepare the slides of the carriage and the slides of the tail stock as TEMPLATES. Such preparation would not involve finish scraping these surfaces but merely smoothing them down and eliminating noticeable burrs and irregularities. These slides, when satisfactorily smooth, would then be used to spot the ways of the bed. Later they would be given a more elaborate treatment and also scraped to an alignment with the ways of the bed. Should this alternative method be adopted, certain changes must necessarily be made in the order relating to the various members. For example, the scraping procedure would then be altered as follows:

1. Level the bed. (See Sec. 26.35 through Sec. 26.39)
2. Prepare slides of carriage as a TEMPLATE
3. Prepare slides of tail stock as a TEMPLATE
4. Scrape the inside and outside ways of the bed.
5. Scrape and align the tail stock
6. Scrape and align the head stock.
7. Scrape and align the compound slide rest assembly
8. Scrape and align the carriage

(The OBJECTIVES as given in the following pages would be equally appropriate for either sequence.)

Sec. 26.3
Exploratory Examination

The first operation in reconditioning a lathe is to dismantle the machine. All members, gearing and parts should be removed and examined for wear. Repair work, involving machine operations should, in so far as possible, be immediately started on those components which need attention. This practice prevents undue delay in returning the machine to service. However, the operator must be judicious in his selection of parts for immediate repair by the grinding and machine departments. If the Exploratory Examination (See Sec. 23.3) reveals that the flat bearings are heavily worn, the need for a major removal of metal is indicated. This may entail a radical shift in gearing, shafts etc. Since this misalignment cannot always be estimated closely, it may be advisable in such cases to delay machining or grinding until after the flat bearings are scrape-finished and correctly aligned and the full requirements made known. What course the operator should follow depends largely on individual circumstances.

Sec. 26.4
Selecting the Datum Point

Another essential preliminary is the identification of the Datum Point of the lathe. In all cases it will be the ways of the bed. The final static alignment tests of the machine are based on the bed ways as the Datum Point.

With the particular type of bearing construction incorporated in the elementary lathe under discussion, the Datum Point refers more specifically to the two outer inverted V-ways of the bed. These surfaces would be scraped first if templates were available, as for example, in factory production. However, on most reconditioning jobs, special templates are not on hand. Therefore, in the proposed sequence of operations, the smaller members of the machine will be utilized for this purpose. This system works out very well and for a lathe is entirely practical.

Having disposed of these preliminaries, we should now level the bed of the lathe. A complete discussion of the procedures to be followed is given in Sec. 26.35 through Sec. 26.39. Unless thoroughly familiar with leveling routine, the reader should turn at once to these important sections.

Sec. 26.5
The Compound Slide Rest

This assembly shown at (5) in Fig. 26.1, consists of two parts, namely:

1. A lower unit called the cross slide for transverse feed.
2. An upper unit called the compound rest for angular feed.

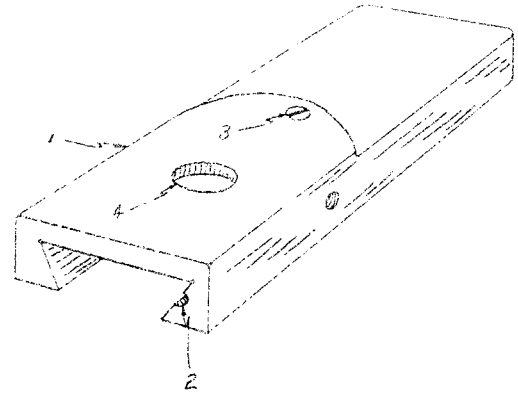

Fig. 26.2 Showing main features of top surface of cross slide.

(1) swivel way (2) adjusting screw slot for tapered gib piece (3) cross feed screw nut clamping bolt (4) pivot hole for compound rest.

Sec. 26.6
The Cross Slide

The lower unit or cross slide consists of four bearing surfaces. Fig. 26.2 and Fig. 26.3 show the upper and lower bearing surfaces, respectively, of the cross slide. They are enumerated below in the order usually preferred for treatment.

1. The swivel way
2. The flat slides
3. The guided slide
4. The gibbed surface.

If the Exploratory Examination reveals the presence of a warp in the casting, the above sequence must be changed so that the flat slides are scraped first and the swivel way last. A discussion of this variation in procedure is reserved for a later paragraph.

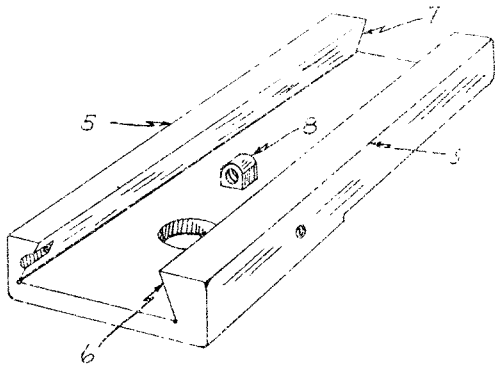

Fig. 26.3 View of bottom surfaces of cross slide. (5) flat slides (6) guided slide (7) gibbed surface (8) cross feed nut.

All the spotting and scraping work on this member is performed at the bench or scraping table. Although this is a minor component of the machine, these operations should not be slighted. Careful work in this stage is amply rewarded later because all surfaces listed above are ultimately utilized for spotting purposes. Special care should therefore be given to them in regard to bearing quality and flatness so that they may perform this function efficiently.

Sec. 26.7
OBJECTIVES: The SWIVEL WAY of Cross Slide

1. To be parallel to the original factory plane.
2. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

This surface, shown at (1) Fig. 26.2, will usually be found to retain some traces of the original factory surface. The reason that the swivel way receives less wear than other surfaces is that it is not a sliding bearing. Although possibly showing only traces of deterioration from this cause it may, nonetheless, be scored on account of grit or chips becoming lodged between it and the compound rest swivel (1) Fig. 26.9, as the latter is pivoted to various angles. It will, therefore, require some attention if only the minimum.

The swivel way is the logical surface to treat first because it is usually in better condition than other surfaces on the same member. Less work is therefore involved in achieving OBJECTIVE NO. 1. Only when a warp is evident in the casting is the sequence changed as mentioned previously in Sec. 26.2. This variation from the normal procedure is discussed hereafter in Sec. 26.9.

In order to accomplish OBJECTIVE NO. 1 it is essential to scrape "straight down" thereby producing a new surface parallel to the original factory new plane. The more closely this requirement is satisfied, the less the cross feed screw will bind when assembly is finally made.

The reason this surface is given the comparatively high number of bearing spots indicated in OBJECTIVE NO. 2, aside from its future utilization as a spotting template, is primarily for the sake of a nice appearance. This surface is in a somewhat conspicuous position and during normal machine operation it is prominently exposed a great part of the time. Therefore, it should be nicely finished.

The swivel way is a simple surface to treat. Spotting is most effectively performed on a SURFACE PLATE. Scraping is best done at a work bench.

Sec. 26.8
OBJECTIVES: The FLAT SLIDES of the Cross Slide

1. To be parallel to the swivel way in vertical plane
2. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The surfaces shown at (5) Fig. 26.3 are examined for wear. Then a test is made to determine what needs to be done to fulfill OBJECTIVE NO. 1. To do this the cross slide is placed on a SURFACE PLATE, with the swivel way in contact with it. A Surface Gage and attached DIAL INDICATOR are used to check from the SURFACE PLATE to all four corners (A), (B), (C) and (D), as shown in Fig. 26.4. (A zero-zero reading at all four locations indicates OBJECTIVE NO. 1 is achieved.) When the amount of misalignment is known, as well as its direction, treatment may be

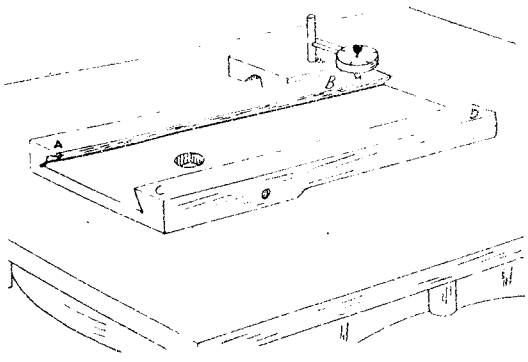

Fig. 26.4 Showing method of testing flat slides of cross slide for parallelism with swivel flat way in vertical plane.

started. These surfaces should be spotted on a SURFACE PLATE, in preference to using a STRAIGHT EDGE.

Both OBJECTIVES are completed simultaneously.

NOTE:

While the flat slides and the swivel way must be parallel to each other in the vertical plane, conditions may be found which would necessitate first scraping the flat slides of the member. For example, this course is called for when the casting is warped. In this case OBJECTIVE NO. 1 would be changed from the present phrasing to read as follows:

Sec. 26.9
OBJECTIVES: FLAT SLIDES of Cross Slide
(Alternative OBJECTIVES and PROCEDURE in case casting is warped.)

1. To be parallel to the axis of the cross feed screw in the vertical plane.
2. Surface bearing quality - as before.

PROCEDURE:

The cross feed nut (8) should be replaced. A test bar is then ground to a slight push fit for insertion in the nut. If accurately ground the bar will center automatically and thus will be located very close to the original position of the cross feed screw in the vertical plane. Measurements may now be taken with a DIAL INDICATOR and stand from the flat slides to the vertical diameter of the test bar. These measurements will furnish information as to the scraping trend. A zero-zero reading at the extremities of the test bar will indicate the achievement of OBJECTIVE NO. 1 above.

If circumstances require the adoption of this alternative procedure then the swivel way will in due course be scraped to correct alignment with the flat slides i.e. parallel in the vertical plane.

Sec. 26.10
OBJECTIVES: The GUIDED SLIDE of the Cross Slide

1. To be parallel to the original factory plane.
2. To preserve the original slope of the angular slide.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The principal purpose of OBJECTIVE NO. 1 is to prevent binding of the cross feed screw in the horizontal plane. Possibly the better method of treating this surface is to scrape "straight down." No check point is employed and the depth of cut is judged solely by the position and coloration of the markings formed by the spotting tool. Good results are probable if the surface is not badly worn.

If the operator works more confidently with a check point, or if an indication of the scraping trend seems desirable, a set up similar to that shown in Fig. 26.5 can be used. The cross feed nut (8) is attached and the cross feed screw is threaded in. The screw is centered in a freely working position, then clamped. A DIAL INDICATOR is fastened to an indicating jig designed to span the flat slides. The instrument is positioned so that the DIAL button is brought in contact with the screw at the horizontal diameter. Readings are taken at both ends of the screw.

This set up will not yield exact results, due in part to the difficulty of exactly centering the feed screw. The scraper must use his judgment as to how far he may safely deviate from a zero-zero alignment of the slide to the feed screw and yet prevent binding.

A superior arrangement, illustrated in Fig. 26.5, would be to make up a test bar

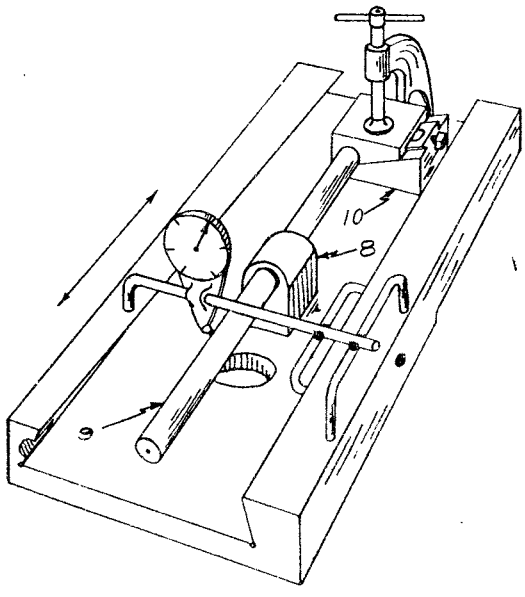

Fig. 26.5 Testing alignment of guided slide of cross slide for parallelism with axis of cross feed screw in horizontal plane.

(8) cross feed nut (9) ground test bar having sliding fit in nut (10) centering device.

which is a sliding fit in the cross feed nut. Such a test bar would align itself and after clamping would be rigid besides providing a smooth surface against which to test. Grinding the bar entails extra effort which may restrict this method to occasions demanding closer supervision of the scraping trend.

OBJECTIVE NO. 2 requires that the original angle of the dovetail side be duplicated as closely as possible. One practice that is helpful is to measure the angle of the guided slide of the cross-slide, or its mateing surface, the guiding way of carriage, before any scraping is performed. This value is then reproduced in the guided slide. Sometimes, even with badly worn surfaces, one mateing member can be spotted on the other and thus provide an approximate indication of the scraping trend in respect to duplication of the original angle.

Spotting to insure flatness will be performed with an ANGLE STRAIGHT EDGE. Precautions should be taken that the tool seats properly against the bearing surface. When necessary enlarge the groove to provide clearance.

All OBJECTIVES are completed together.

Sec. 26.11

OBJECTIVES: The TAPERED GIBBED SURFACE of the Cross Slide.

(The cross slide gib will be tapered)

1. To be parallel to the original factory plane.
2. To have a surface quality of 5 - 10 bearing spots per square inch.

PROCEDURE:

The tapered surface, shown at (7) in Fig. 26.3, is the one to which the cross slide tapered gib is fitted. Ordinarily this surface will be found unworn since it is not a sliding bearing. However, it may be burred and there is always the possibility of a warp in the casting. To test for these conditions, the surface is spotted with an ANGLE STRAIGHT EDGE, though before employing this tool, it is good practice to inspect the groove for clearance. When there is no groove it is advisable to cut one. If a warp is not disclosed, OBJECTIVE NO. 1 should be easily fulfilled since it involves the removal of but a small amount of metal. The angle may be checked by spotting with the gib way of the carriage. To accomplish this the cross slide because of its taper must be swiveled slightly.

Both OBJECTIVES are to be fulfilled simultaneously.

This completes all the bearing surfaces on the cross slide. These several scrape-finished surfaces may now be used as templates to assist standard spotting tools in fitting the appropriate bearing surfaces of both the carriage member and the compound rest.

Sec. 26.12

The Compound Rest

The compound rest, shown at (5) in Fig. 26.1, is mounted on the cross slide and carries the cutting tool. This component is capable of swiveling through a full 360° circle, thus permitting steep tapers to be machined on a piece of work.

The compound rest consists of two parts, namely:

1. The compound rest top or upper unit.
2. The compound rest swivel or lower unit.

For speed and convenience in scraping, the preferred order of operations is to treat first the upper unit, followed by the lower unit. If this is done, standard spotting tools can be utilized. When finished the upper unit is an efficient spotting tool for the more difficult lower unit of the compound rest. Should the reverse order be followed, either special spotting tools or a complicated set up for checking would be required. It is only common sense, therefore, to simplify the procedure by starting with the upper unit.

Sec. 26.13
The Compound Rest Top

Fig. 26.6 and Fig. 26.7 show the top and bottom surfaces, respectively, of the upper

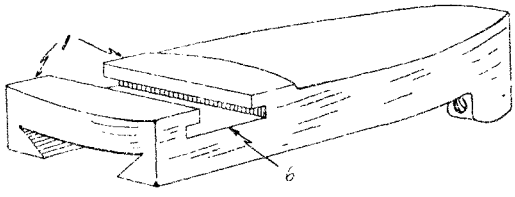

Fig. 26.6 View of top surface of upper unit of compound rest.

(1) tool post ring support (6) T-slot for tool post block

unit of the compound rest. It has four surfaces which are scraped. They are listed below in the preferred sequence of scraping operations:

1. The tool post ring support
2. The flat slides
3. The guided slide
4. The tapered gibbed surface.

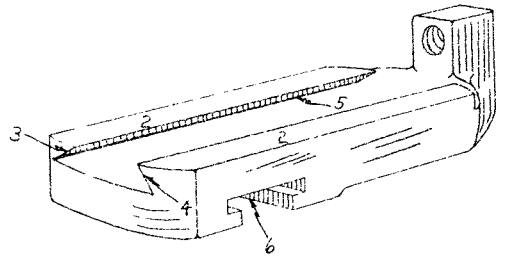

Fig. 26.7 View of bottom surfaces of upper unit compound rest.

(2) flat slides (3) guided slide (4) tapered gibbed surface (5) clearance groove (6) T-slot for tool post block.

Sec. 26.14
OBJECTIVES: The TOOL POST RING SUPPORT of the Compound Rest Top.

1. To be parallel to the original factory plane.
2. To have a surface quality of 5 - 10 bearing spots per square inch.

PROCEDURE:

The tool post ring support shown as (1) in Fig. 26.6 is not a sliding bearing surface, but it may be worn or even scored due to chips being forced into the surface when the tool post is clamped. It can easily be spotted on a SURFACE PLATE to determine its condition, then scraped for OBJECTIVE NO. 1. A suitable progress check is made by measuring with a depth micrometer from the tool post ring support (1) to the bottom of the T-slot, shown as (6) in the figure abovementioned. (When manufactured the T-slot was machined parallel.) Similar readings obtained at several points indicate the surface is parallel to the original factory plane.

The surface bearing quality required by OBJECTIVE No. 2 is acquired simultaneously.

NOTE:

The tool post ring support is chosen as a check point for the flat slides (2) in Fig. 26.7 because, if not badly worn or scored, it can quite easily be scraped parallel to the original factory surface. Sometimes, however, circumstances dictate the opposite course; that is the flat slides should be the check point for the tool post ring support surface. In such a case, the flat slides take precedence and are scraped first, For example, this situation might arise if the tool post ring support surface is excessively worn and the flat slides are in relatively good condition. An unusual machine design may also be reason to alter the recommended sequence of scraping.

Sec. 26.15
OBJECTIVES: The FLAT SLIDES of the Compound Rest Top.

1. To be parallel to the tool post ring

support surface in the vertical plane.
2. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The flat slides of the compound rest top, shown as (2) in Fig. 26.7, are a divided surface and constitute nothing new in the way of a scraping problem. A simple spotting job on a SURFACE PLATE will reveal the condition of the flat slides. Once scraping has started, progress towards OBJECTIVE NO. 1 is checked by the set up shown in Fig. 26.8. An identical reading on the DIAL INDICATOR is required at

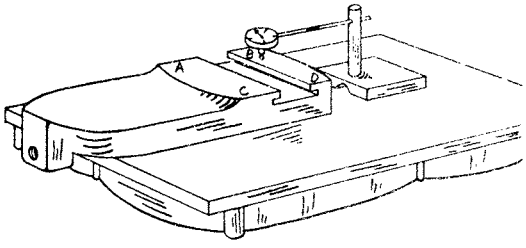

Fig. 26.8 Method of checking parallelism of flat slides of compound rest with the tool post ring support.

points (A), (B), (C) and (D). The scraping is continued on the flat slides until they are parallel to the tool post ring support in the vertical plane.

To assure greater accuracy, a modification of the preceding check is sometimes adopted. The compound rest top is laid on a SURFACE PLATE with the flat slides in contact. A ground or scraped PARALLEL is set, first in a longitudinal direction and then in a transverse direction, on the tool post ring support surface. It is not clamped but is held in position with the hand. Measurements with a DIAL INDICATOR and a SURFACE GAGE are made from the SURFACE PLATE to both extremities of the PARALLEL. A zero-zero reading is essential.

A suitable surface bearing quality is scraped in at the same time to secure OBJECTIVE NO. 2.

NOTE:

If the flat slides of the compound rest top were the first surface of this member to be scraped, OBJECTIVE NO. 1 would be altered to read:

1. To be parallel to the axis of the compound rest screw in the vertical plane.

PROCEDURE:

The treatment of the flat slides would be directed to obtaining correct alignment with the feed screw. Following this the tool post ring support is aligned parallel with the flat slides.

Sec. 26.16

OBJECTIVES: The GUIDED SLIDE of the Compound Rest Top.

1. To be parallel to the axis of the compound rest screw in the horizontal plane.
2. To preserve the original slope of the angular slide.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

Before any removal of metal is attempted, the surface should be examined for wear. In many cases, abrasion on the guided slide is not excessive and merely scraping "straight down" will accomplish the OBJECTIVES. (Refer to Sec. 23.21)

However, when this surface is badly worn it is advisable to employ a suitable check point, one that has retained its original alignment reasonably well. Such a check point is the feed screw of the compound rest. To utilize this feature the compound rest bushing, feed screw assembly etc., must be re-inserted. The feed screw is then centered and blocked in its working position. This is essential because of the side play of the journal of the screw in its bushing. A DIAL INDICATOR mounted on an Indicating jig is used to measure from the guided slide to both ends of the screw. This testing procedure is similar to that shown in Fig. 26.5 (Guided slide of cross slide). A zero-zero reading satisfies OBJECTIVE NO. 1.

In place of the screw, which does not offer the best possible surface for stable readings, a test bar may be substituted. It should be ground to a light push fit into the compound rest bushing. If made to the

proper diameter it will automatically center itself besides providing an accurate, smooth test surface.

Treatment to achieve OBJECTIVE NO. 2 likewise depends upon the degree of deterioration of the surface. If this is slight, merely scraping "straight down" will accomplish the purpose. Otherwise, the operator must either prepare a special template having the required angle; employ a vernier protractor and make periodic checks as the work progresses; or utilize the guiding way of the compound rest swivel for spotting purposes to retain the desired angle.

Spotting, to obtain the desired flatness and surface quality demanded by OBJECTIVE NO. 3 is capably performed with an ANGLE STRAIGHT EDGE. Before applying this tool for the first time it is advisable to inspect the groove for clearance.

All OBJECTIVES are completed simultaneously.

Sec. 26.17

OBJECTIVES: The TAPERED GIBBED SURFACE of the Compound Rest Top.

(The gib piece will be tapered)

1. To preserve the original slope and taper.
2. To have a surface quality of 5 - 10 bearing spots per square inch.

PROCEDURE:

Seldom is difficulty experienced in accomplishing OBJECTIVE NO. 1. A warp in the casting would, of course, be a serious matter, and burrs sometimes cause trouble. These faults can be easily recognized by applying a small ANGLE STRAIGHT EDGE and spotting the surface carefully.

Clearance of the spotting tool in the groove is essential if the markings are to be accepted as trustworthy. Incidentally, if a dovetail spotting template was used on the guided slide, it may also be applied here to maintain the angle.

OBJECTIVE NO. 2 should be completed at the same time. The bearing quality specified is ample since this is not a sliding bearing surface. The tapered gib piece of the compound rest has a fixed contact with it.

All surfaces of the compound rest top are now finished. This upper unit will next be employed to spot the lower unit, or compound rest swivel.

Sec. 26.18

The Compound Rest Swivel

Fig. 26.9 and Fig. 26.10 illustrate views of the bottom and top surfaces respectively of the lower unit of the compound

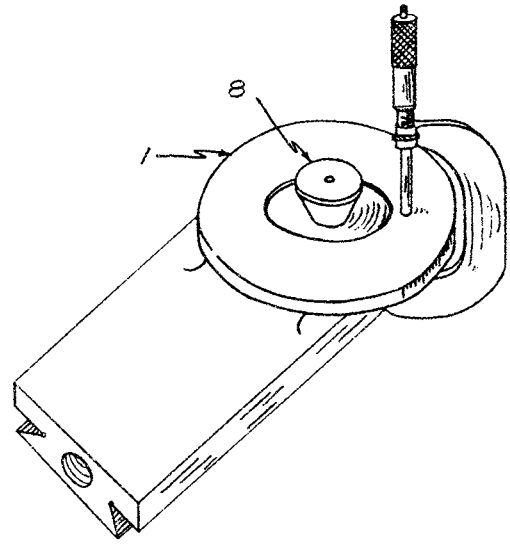

Fig. 26.9 View of bottom surface of compound rest swivel testing flat ways for parallelism with the swivel slide in the transverse direction.

(1) graduated swivel slide (8) clamping boss.

rest. The bearing surfaces of the lower unit, or compound rest swivel, are identified below and enumerated in the correct order they should be scraped.

1. The swivel slide
2. The flat ways
3. The guiding way
4. The gib way.

Sec. 26.19

OBJECTIVES: The SWIVEL SLIDE of the Compound Rest Swivel

1. To be parallel to the original factory plane.
2. To be fitted to the swivel way of the cross slide with a surface quality of 5 - 10 bearing spots per square inch.

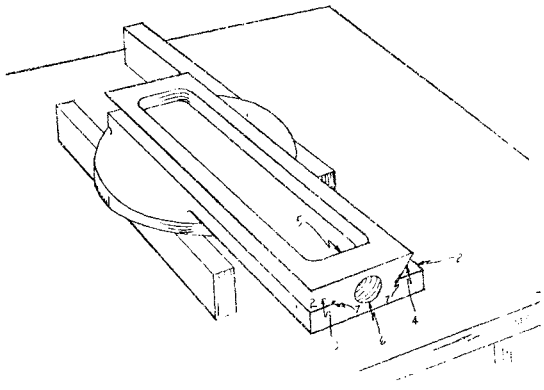

Fig. 26.10 View of top surfaces of compound rest swivel.

(2) flat ways (3) guiding way (4) gib way (5) bridge dovetail (6) hole for inserting compound rest feed screw nut (7) grooves

PROCEDURE:

During normal operation of a lathe, very little wear occurs on the swivel slide of the compound rest swivel, shown as (1) in Fig. 26.9. It is not a sliding bearing but it may be scored as a result of chips lodging between it and the swivel way of the cross slide immediately below.

Analysis of the swivel slide shows that the clamping boss, shown as (8) in Fig. 26.9, complicates the treatment. The boss is an integral part of the casting, hence cannot be removed. Consequently, a standard SURFACE PLATE is not suitable to spot this surface. Moreover, for ordinary reconditioning jobs, it would be too expensive to make up a special spotting gage having a central hole to slip over the protruding boss.

This problem, however, is easily solved if the scraper has followed the logical sequence outlined in the preceding pages. Thus we find the swivel way of the Cross Slide has already been scrape-finished and is available as a template. To utilize it, a film of marking medium is spread on the swivel way of the cross slide after which the swivel slide of the compound rest is placed in contact.

The clamping boss now acts as a pivot for the compound rest swivel. The marking medium is transferred by turning one unit on the other. Another advantage of this method is that the fitting is practically automatic.

Little difficulty will be experienced in completing OBJECTIVE NO. 1, if attention is given to scraping "straight down". Care should be exercised in scraping towards the outer perimeter of the surface to avoid rounding off the edge and thus mutilating the graduations. This can be avoided if the blade of the scraper tool approaches the edge at a tangent instead of broadside.

The operator should plan the job so that both OBJECTIVES are attained together.

Sec. 26.20

OBJECTIVES: The FLAT WAYS of the Compound Rest Swivel

1. To be parallel to the swivel slide in vertical plane.
2. To be fitted to the flat slides of the compound rest top, with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

On most lathes inspection shows that the flat ways of the compound rest swivel (2) Fig. 26.10, are quite visibly worn. However, reconditioning is simplified because it is possible to use the mateing surfaces as a template. To this end, the flat slides of the compound rest top, which previously was scrape-finished, are coated with marking medium. The components are placed together and the transfer is made in the usual manner. To assure flatness, supplementary spotting should be performed with an ANGLE STRAIGHT EDGE applied alternately. In this manner the flat ways are fitted as specified by OBJECTIVE NO. 2.

Occasionally, the scraping is interrupted while tests are made for parallelism as required by OBJECTIVE NO. 1. One possible method would be to measure with a micrometer between the swivel slide and each flat way, as shown in Fig. 26.9. With these measurements the parallelism can be checked in the transverse direction.

To check parallelism in the longitudinal direction, the swivel slide of the member is mounted on PARALLELS, placed on a SURFACE PLATE. (See Fig. 26.10) Then a DIAL INDICATOR attached to a Surface

Gage is used to measure from the SURFACE PLATE to detect any deviation from parallelism on either flat way in the longitudinal direction.

Clearance is particularly important, not only in relation to the grooves when spotting, but also clearance between the bridge dovetail of the lower unit, shown as (5) in Fig. 26.10 and the upper unit. This matter can be investigated by means of the Light Test. (Refer to Sec. 18.11)

Both OBJECTIVES are attained simultaneously.

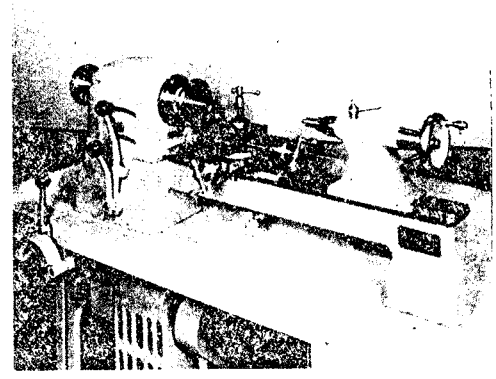

PLATE 19. Precision bench lathe completely assembled. Note conventional angular way and flat way. (Courtesy - Elgin Tool Works.)

Sec. 26.21

OBJECTIVES: The GUIDING WAY of the Compound Rest Swivel

1. To be parallel to the original factory plane.
2. To be fitted to the guided slide of the upper unit of the compound rest with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The guiding way of the compound rest should be carefully examined to determine the amount of wear. All discernible clues are evaluated because it is essential to rescrape this surface parallel to the plane of the original factory surface. Unless this is done there will be unnecessary binding of the compound rest feed screw in the feed screw nut when assembly is made.

NOTE:

In all cases where treatment of bearing surfaces shifts the position of a feed screw or feed screw nut, some binding is inevitable, unless wear at another point compensates for it. However, the operator should always try to keep the binding to a minimum by scraping the bearing surfaces "straight down".

There are several methods of insuring against needlessly aggravating this condition. In some designs the feed screw nut is a press fit into the casting. If so, it may be removed and a test bar ground to a light push fit is inserted in the nut hole (6) Fig. 26.10. Essentially, this is a test bar substituting for the compound rest feed screw. When the nut is an integral part of the casting, the screw may be threaded through after first removing it from the upper unit to which, normally, it is attached. The screw in such a case is used as a test bar from which to align the guiding way.

If the guiding way is tested using the feed screw as a check point, OBJECTIVE NO. 1 could be rephrased to read:

1. To be parallel to the axis of the feed screw in the horizontal plane.

Although these procedures are acceptable they are not without their faults. For instance, there is a cumulative error

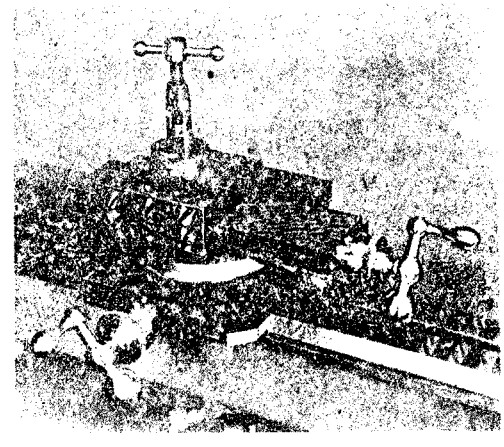

PLATE 20. Close-up of the compound slide rest clamped to the ways of a bench lathe. (Courtesy - Elgin Tool Works.)

induced by removing metal from the guiding way and also, previously, from the guided slide of the upper unit. Thus the axis of the feed screw nut will be misaligned with the axis of the feed screw when the two units are assembled. This is unavoidable but explains why some binding will occur in any case when rescraping the bearing surfaces. It should not be needlessly increased though, through failure to attain OBJECTIVE NO. 1 as closely as possible.

The feed screw has a certain amount of side play in the nut which can take up the offset to some extent. However, the amount of metal removed from the several surfaces often makes it necessary to relocate the threaded nut. This operation is not part of a scraping operator's job but briefly it consists of offset boring and threading a larger diameter hole, or as an alternative, the insertion of a bushing with the threaded hole set over from center by the necessary amount.

In spotting this surface it is preferable to alternate between a small ANGLE STRAIGHT EDGE and the mateing surface i.e. the guided slide of the Compound Rest Top. If both are properly manipulated when transferring the marking medium and scraping is skillfully performed, a correctly matching angular slope will be produced in the guiding way and the surface will be flat.

The requisite surface bearing quality is secured simultaneously.

Sec. 26.22

OBJECTIVES: The GIB WAY of the Compound Rest Swivel

1. To match the slope of the gibbed surface of the compound rest top.
2. To be parallel to the guiding way of the compound rest.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

In treating the gib way, shown at (4) in Fig. 26.10, one should not lose sight of the fact that preparation must be made for a tapered gib piece. Thus if OBJECTIVE NO. 1 is not strictly observed, the gib piece must be fitted to match an objectionable transverse taper. (See Sec. 17.27) That is, in addition to its normal longitudinal taper, there will be also a transverse taper. Needless to say, a single experience in coping with this condition is sufficient to prove its difficulty.

To produce the identical angular slope in the gib way it should be spotted with the gibbed surface of the compound rest top. It is good practice to apply an ANGLE STRAIGHT EDGE alternately to maintain flatness. If the slope is duplicated it will be an easy matter to fit the tapered gib into the slot between the surfaces of the two mateing members.

On those machines whose design or construction prevents swiveling the upper unit, to allow its gibbed surface to come in contact with the gib way of the lower unit for spotting purposes, other methods are needed. One alternative is to prepare a DOVETAIL SPOTTING TEMPLATE made especially for this purpose. Another method is to measure with a protractor at frequent intervals as the work progresses. Although not so convenient to employ, these tools will help to generate matching angles. In this manner the subsequent fitting of the tapered gib piece is expedited.

OBJECTIVE NO. 2 can be checked by using two short PRECISION CYLINDERS of appropriate diameter placed in the dovetails. Measurement with a micrometer is performed as shown in Fig. 26. 11. Identical measurements must be attained at both end positions to qualify.

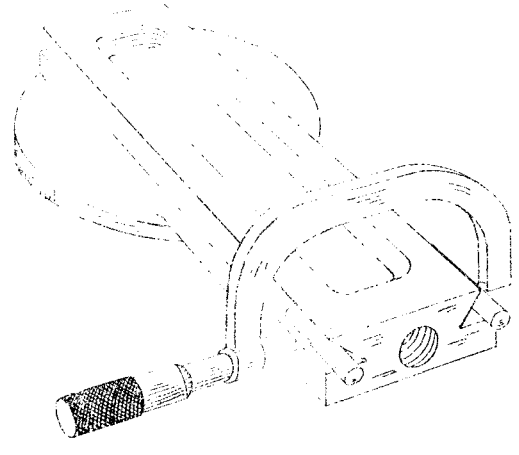

Fig. 26.11 Arrangement for testing gib way of compound rest swivel for parallelism to guiding way.

All OBJECTIVES are completed together.

NOTE:
Good practice favors inspecting the groove (7) for clearance before commencing spotting.

Sec. 26.23
OBJECTIVES: The TAPERED GIB of the Compound Rest Top.

1. Tapered side to be fitted to the gibbed surface of the upper unit of the compound rest with a surface quality of 5 - 10 bearing spots per square inch.
2. Straight side to be fitted to the gib way of the lower unit of the compound rest, with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The tapered gib piece of the compound rest fastens the upper unit of this member to the lower unit. In comparison to the size of other tapered gibs utilized on the average machine tool it is quite small. However, there is no essential difference in the scraping and spotting procedure performed on it. For details on measuring for a tapered gib and fitting it, the reader is referred to Sec. 17.17 on Tapered Gibs.

When the gib piece is nearly completed, the guiding way and gib way of the swivel should be again checked for parallelism. The appropriate procedure is to apply the Sliding Member Test, which is discussed in Sec. 22.11. Not until parallelism is proved, should the gib piece be scrape-finished.

Sec. 26.24
OBJECTIVES: Alignment of COMPOUND SLIDE REST.

1. Movement of Compound Rest Top to be parallel with flat ways of cross slide in vertical plane.

PROCEDURE:

To insure that a cumulative error (Sec. 23.16) has not developed in the subassembly of the compound slide rest during treatment of the individual components, an alignment test should be conducted at this point. To perform it the members are assembled one on the other. The slide rest is then laid on a SURFACE PLATE and a DIAL INDICATOR is attached as shown in Fig. 26.12. The DIAL button is adjusted to rest either on the SURFACE PLATE or on a PARALLEL. The compound rest is swiveled to various positions and its movement is tested for parallelism with the flat ways of the cross slide in

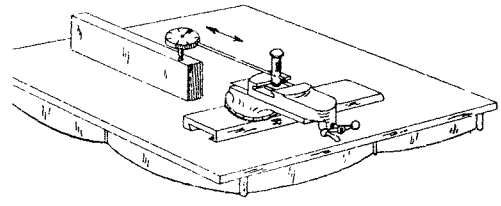

Fig. 26.12 Movement of compound rest top parallel to flat slides of cross slide in vertical plane. Tolerance max. .0035 " per foot.

both the transverse and longitudinal directions. It will be entirely satisfactory in this respect if the tolerance shown in Fig. 26.12 is not exceeded.

The compound rest may now be laid aside while the next member of the lathe i.e. the carriage, is treated.

Sec. 26.25
The Carriage

The carriage, known also as the saddle, spans the bed of the lathe. It is guided longitudinally by the outer ways of the bed. This member supports the assembly called the Compound Slide Rest, on top, and carries the apron on the front side.

The carriage has two groups of bearing surfaces.

GROUP 1

The upper side, shown in Fig. 26.13, is associated with the compound slide rest. It is a transverse way of dovetail cross section. Sometimes called the Cross Slide Way, Cross Slide Bridge etc., it consists of the following surfaces:

1. The flat ways.
2. The guiding way.
3. The gib way.
4. Bridge dovetail.

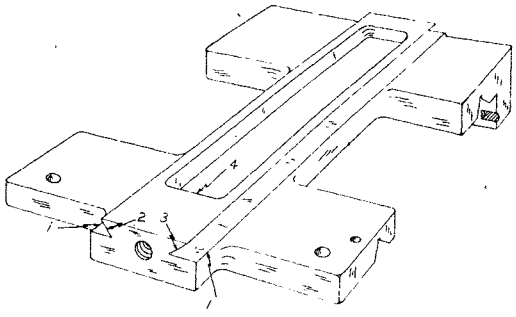

Fig. 26.13 View of upper surfaces of carriage.
(1) flat ways (2) guiding way (3) gib way
(4) bridge dovetail

GROUP 2

The lower bearing surfaces, represented in Fig. 26.14, are associated with the lathe bed and comprise the following:

(*) 5. The front V-slide
(*) 6. The rear V-slide
7. The rear carriage gib bracket bearing.

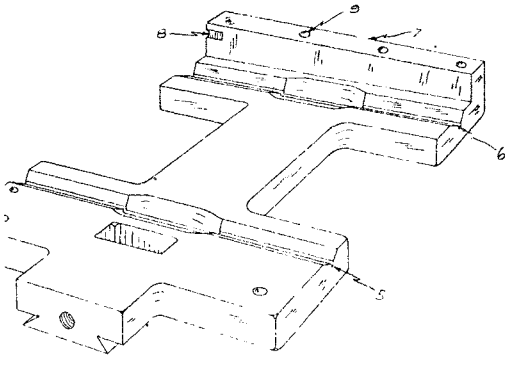

Fig. 26.14 View of lower surfaces of carriage.
(5) front outer V-slide (6) rear outer V-slide
(7) tapered rear carriage bracket bearing
(8) slot for head of adjusting screw of gib
(9) tapped holes for gib bracket.

Special attention should be given to the carriage surfaces designated with a (*) in order to provide them with an extra good surface bearing finish and flatness. This is essential because they are used during various phases of the scraping routine as spotting templates for the lathe bed.

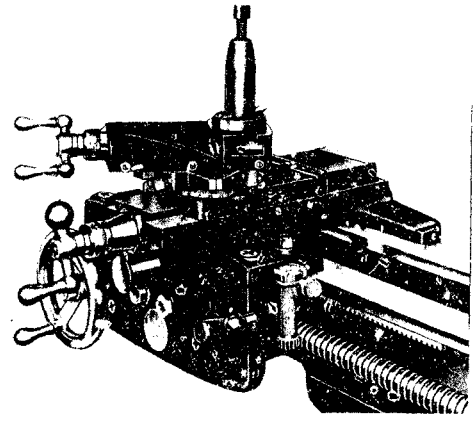

PLATE 21. Close-up of carriage supporting compound slide rest and apron mounted on flat ways of lathe bed. (Courtesy - Atlas Press Company)

Sec. 26.26
OBJECTIVES: The FLAT WAYS of the Carriage

1. To be parallel to the original factory plane.
2. To be fitted to the flat slides of the cross slide with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

Because of frequent usage the flat ways of the carriage are one of the most heavily worn surfaces on the lathe. Rarely, therefore, would any frostings or scraping tool marks be visible on them to assist the operator in determining the plane of the original factory surface. While this multiplies the difficulties, it accents the importance of OBJECTIVE NO. 1 which if achieved will prevent unnecessary binding of the cross feed screw.

There are several procedures which may be used to provide a guide to the original factory plane. They may be briefly summarized as follows:

One method will test the flat ways by indicating the degree of parallelism with the axis of the feed screw. Another method will check the flat ways by utilizing the bridge dovetail as a check point but it is not a clear cut, definite test. Still another

procedure for locating the original plane would be to measure from the V-slides underneath the carriage to the flat ways.

Before applying one or more of the checks outlined above, it is frequently desirable to prepare the worn surface of the flat ways so that more accurate testing is possible. To indicate their physical condition, a small ANGLE STRAIGHT EDGE somewhat longer than the flat ways is required. Alternately the flat slides of the cross-slide are utilized to apply spotting medium.

The surfaces are treated to a few cycles of spotting and scraping, trying primarily to remove roughness and to obtain flatness. When the flat ways have a reasonable smoothness, one or more of the aforementioned checks should be executed.

Before making a selection, the operator will weigh the speed of one method against the greater accuracy of another, in relation to existing conditions. The decision should be in favor of that method which provides the maximum information consistent with economy of time and effort. The tests discussed below will be repeated periodically as the scraping progresses until the OBJECTIVES are attained.

1. In the first procedure the cross feed bushing is threaded in and the feed screw assembly is inserted. Then the feed screw is centered and blocked by any suitable means. In lieu of the screw, a test bar having a slight press fit into the cross feed bushing may be made up. In some cases, close centering and greater stability of the DIAL readings compensates for the extra effort of precision grinding a test bar. Making a test bar for this double duty may, after all, be quite practicable since it can also be used when checking the next surface which is the guiding way. After attaching a DIAL INDICATOR to a PARALLEL the latter is placed on one of the flat ways. The contact button of the DIAL is set on the test bar or feed screw at the vertical diameter. By moving the PARALLEL from one end of the flat way to the other, variations in the distance from the flat way to the test bar or screw is indicated by the DIAL reading. The operation is then repeated on the other flat way. The scraping operations on the bearings should be planned so as to obtain an identical reading at both ends of the test bar and from either flat way. Such a reading on the DIAL would indicate the attainment of OBJECTIVE NO. 1.

2. Another qualified check is performed by measuring from the bridge dovetail as shown in Fig. 26.15. The reason this unworn surface may be used with some likelihood of success is that, during manufacture, the bridge was machined parallel to

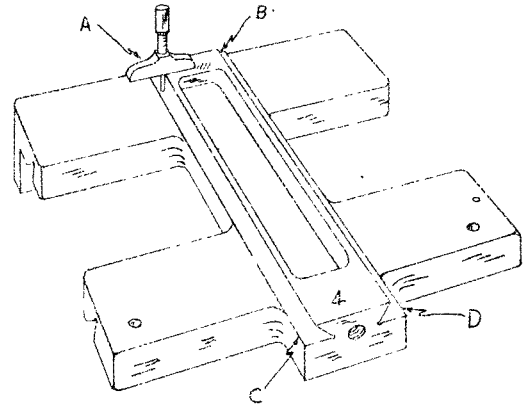

Fig. 26.15 Method of checking flat ways of carriage for parallelism with original surface. Measurements made from bridge dovetail (4) to flat ways at positions (A), (B), (C) and (D).

the flat ways and will, therefore, denote the original plane. To utilize it, measurements are made with a depth micrometer from the bridge dovetail to the flat ways at both ends. Readings taken at positions (A), (B), (C) and (D) must be equal before OBJECTIVE NO. 1 is achieved.

3. A third procedure which can be utilized to locate the original plane is indicated in Fig. 26.16. Briefly, it consists of a measurement from the flat ways of the carriage to the V-slide underneath. Equal diameter test bars are inserted in each V-slide and the assembly is placed on a SURFACE PLATE. A small ground block is interposed between the surface and the button of the DIAL to obtain an average reading from the worn flat ways. Identical measurements at all four corners will indicate the attainment of OBJECTIVE NO. 1. The foregoing test is not positive because the V-slides of the carriage have not as yet received any treatment, but in some circumstances it will prove helpful to the scraper

An alternative set up is illustrated in Fig. 26.30 and Fig. 26.32. From a study of these views we see that a PRECISION LEVEL may be used to register the closeness that a bearing surface approaches parallelism with the original factory plane. On a correctly aligned lathe the flat ways of the carriage would be level measuring in both the longitudinal and transverse directions.

So much for the methods of finding the original factory plane of the flat ways. We will now consider the requirements for fitting the flat ways as specified in OBJECTIVE NO. 2. To facilitate this operation a coating of marking medium is applied to the flat slides of the cross-slide and transferred in the usual manner. The spotting procedure should be supplemented by applying the ANGLE STRAIGHT EDGE alternately.

NOTE:

Before any spotting is performed all grooves on this member should have been examined for clearance. This is done to prevent the cross-slide from riding a radius in the corner of its mateing member while spotting, thereby preventing a proper fit of the ways to the slides i.e. area contact. It will also provide assurance that the ANGLE STRAIGHT EDGE is spotting properly. The bridge dovetail should also be checked for clearance with the cross slide by applying the Light Test (Sec. 18.11)

Sec. 26.27

OBJECTIVES: The GUIDING WAY of the Carriage.

1. To be parallel to the cross feed screw in the horizontal plane.
2. To be fitted to the guided slide of the cross slide with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

To fit the guiding way of the carriage to the guided slide of the cross slide, the latter surface, which is already scrape-finished, is used as a spotting template. Marking compound can be spread on it and transferred to the guiding way in the usual manner. In order to expedite the spotting and to assure the requisite flatness, it is good practice to alternate with an ANGLE STRAIGHT EDGE of adequate length. Before any spotting is done, however, it is advisable to check the clearance of the groove and also of the bridge dovetail, although strictly speaking, this should have been done preceding the transfer of marking medium to the adjacent flat ways.

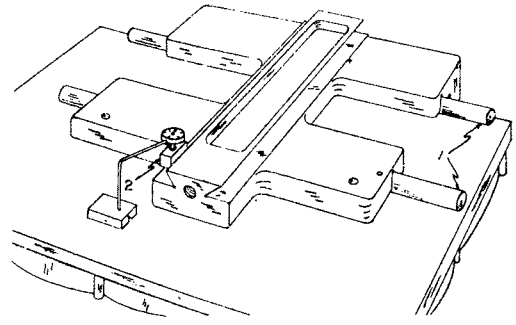

Fig. 26.16 Testing flat ways of carriage for parallelism with V-slides to determine original factory-plane.

(1) precision cylinders (2) gage block

To check for OBJECTIVE NO. 1, a test bar ground to a light push fit is inserted into the cross feed bushing. An indicating jig of a form that will ride on both flat ways and against the guiding way is now made up. (Refer to Sec. 16.13) After attaching a DIAL INDICATOR and setting the button in contact with the test bar at the horizontal diameter, the device is moved from end to end of the guiding way. A zero-zero reading will indicate parallelism.

Both OBJECTIVES are completed simultaneously.

Sec. 26.28

OBJECTIVES: The GIB WAY of the Carriage

1. To match the slope of the gibbed surface of cross slide.
2. To be parallel to the guiding way in the horizontal plane.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

In dealing with OBJECTIVE NO. 1 we will utilize the gibbed surface of the cross slide as a spotting template to help form an identical angular slope on the gib way. This is desirable because a tapered gib

piece inserts between these surfaces. By preventing a transverse taper the gib will be more easily fitted. The operation is performed by coating the template surface with a film of marking medium and moving the affected surfaces into contact by swiveling the cross slide. An ANGLE STRAIGHT EDGE should be applied alternately to assure flatness.

Progress towards OBJECTIVE NO. 2 can be ascertained by means of the DIAL INDICATOR and the Indicating Jig used just previously.

An alternative method, employing precision cylinders and a micrometer, as shown in Fig. 26.11, may also be adopted.

OBJECTIVE NO. 3 is attained simultaneously.

Sec. 26.29

OBJECTIVES: The TAPERED GIB of the Cross Slide.

1. Tapered side to be fitted to the gibbed surface of the cross slide with a surface quality of 4 - 5 bearing spots per square inch.
2. Straight side to be fitted to the gib way of the carriage with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

This gib piece fastens the cross slide to the carriage ways which have just been completed. Since the procedure to be adopted in scraping a tapered gib has been adequately treated elsewhere, only the main points will be summarized here. In producing the tapered gib, the principal consideration is to fit it to the correct taper. It is not finished though until the Sliding Member Test (Sec. 22.11) of the cross slide on the carriage ways has been conducted. The Shake Test (Sec. 22.5) for convexity should also be performed. Not until the operator is satisfied that both tests have been satisfactorily completed, and the ways are parallel and flat, should the tapered gib be scrape-finished. For futher details refer to Sec. 17.24 on Tapered Gibs.

Sec. 26.30

OBJECTIVES: The V-SLIDES of the Carriage

1. To duplicate the original V angle
2. To maintain the original center-to-center distance between the axes of the V-slides.
3. To be parallel in the horizontal plane.
4. To be square with the guiding way of the carriage.
5. To be parallel to flat ways of carriage in the vertical plane.
6. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

When the V-slides of the carriage are to be employed as a template, as is common practice, two courses of action are open. Either the V-slides can be prepared solely for use as a spotting template for the ways of the bed, or they can be given this treatment plus the required alignment with the ways of the carriage.

Should the first course be adopted then OBJECTIVES NO. 4 and NO. 5 may be disregarded. The alignments which they specify are accomplished subsequently after the ways of the bed and the head stock and tail stock members are completed. This procedure finds favor with many scrapers, particularly since the V-slides of carriage are comparatively easy to prepare as a template. Another favorable feature of this plan is that the alignments of the carriage can be more rigidly controlled if the other members of the lathe are dealt with first.

The second method, which requires fulfilling all of the OBJECTIVES above

PLATE 22. Testing the cross-slide dovetail of a carriage using a special square having V-slides fitted to the bed ways and a sliding block having a DIAL INDICATOR mounted with the INDICATOR button resting on the square. (Courtesy - South Bend Lathe Works.)

stated, will be discussed in the following paragraphs. The advantage of this system is that by attaining all of the OBJECTIVES now, the amount of work necessary at the final alignment of the carriage will be materially reduced.

Since, as we have pointed out, it is common practice to use the carriage member of the lathe as a spotting template, special care should be observed with either method, so that the bearing surfaces of the V-slides are truly flat, possess adequate bearing quality and are correctly aligned to each other.

The number of OBJECTIVES which must be fulfilled in perfecting the V-slides of the carriage gives an indication of the difficulty of reconditioning them. However, by interspersing throughout the scraping routine, the tests hereafter described, much of the apparent difficulty will be overcome.

It is possible to check for OBJECTIVE NO. 1 by making up a special template having the desired angle. A more ambitious plan which would also help satisfy OBJECTIVE NO. 2 is to build a manufacturing jig with correctly spaced and parallel vees, duplicating both outside inverted V-ways of the bed. These proposals involve considerable extra work and are seldom considered by operators planning a reconditioning job.

The method most favored for the occasional job utilizes the ways of the bed as a spotting template. But the reader may well ask "To what extent can the bed ways, worn as they are, be used to help renovate the carriage V-slides?"

The answer to this question is: The bed ways perform two functions, namely:

1. They assist in retaining an angle in the carriage V-slides approximately equal to the original factory angle. This is indicated by a more or less uniform marking transferred to the bearing surfaces of the carriage.
2. The bed ways regulate and control the proper spacing of the carriage V-slides. Correct spacing is denoted by uniform coloration. There should not be signs of heavy pressure on one side of a V-slide, and an indication of only light pressure on the other side of the same V-slide.

How efficiently the outer bed ways perform their intended function depends, of course, on their physical condition. Frequently, it will be found that the section of the outer bed ways, at the tail stock end, shows only moderate wear. The reason for this is that, under average working conditions, the carriage is seldom stationed there. Consequently, there is usually available at that end of the bed, a bearing surface in fair condition and of adequate length with which to spot the carriage slides.

Although the inverted V-ways of the bed will be somewhat worn, still in most cases, enough of the original surface remains to provide a very close approximation of the original angle and center to center distance.

The operations that follow are the familiar ones of spotting and scraping, interrupted periodically for checks to disclose progress toward the goal. The number of checks which must be conducted consecutively, from time to time, introduces an element of complexity which is unavoidable.

After coating the ways of the bed with marking compound, the carriage is placed on top, as shown in Fig. 26.17. Transfer of the medium is effected by moving the carriage back and forth with a long spotting movement of about 6". This exaggerated movement is resorted to so that the inverted V-ways will transfer an average marking to the V-slides of the carriage.

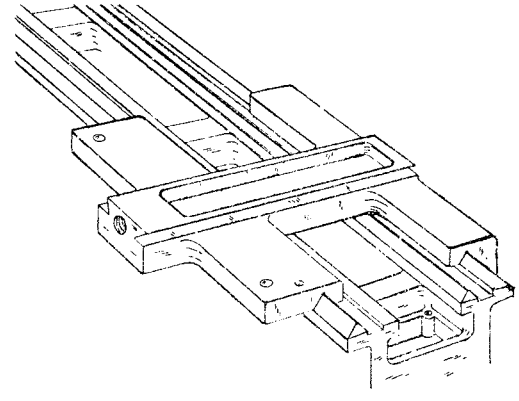

Fig. 26.17 Spotting the V-slides of carriage on the inverted V-ways of the bed at the tailstock end to prepare them to function as a TEMPLATE.

The principal purpose of spotting the carriage V-slides on the outer ways of the bed, is to keep a check on OBJECTIVES NO. 1 and NO. 2. It is intended chiefly for observation. Little or no scraping should be performed on the carriage V-slides on the basis of these markings, particularly during the finishing stages, because the inverted V-ways of the lathe bed are definitely known to be inaccurate. That is, they lack the accuracy of precision gages and tools.

The markings transferred by the bed ways are utilized merely to indicate by their coloring and their position, how closely OBJECTIVES NO. 1 and NO. 2 are approximated. It is obvious that the worn condition of the bed ways reduces their usefulness as a spotting template for indicating flatness and bearing quality during even the initial phases of the job. And throughout the finishing stages, when requirements are naturally more exacting, their trustworthiness in this respect is even more in question.

To indicate flatness and surface bearing quality in these circumstances, reliance will be placed in an ANGLE STRAIGHT EDGE applied to the carriage V-slides. This tool is used to spot separately both sides of each carriage V-slide. It is these true markings, indicating relative flatness, which are removed by the scraping tool. In other words, the requisite flatness and surface bearing quality are worked into the carriage V-slides by employing a precision tool, i.e. ANGLE STRAIGHT EDGE.

The V-angle produced in the carriage V-slides by this procedure will in most cases be close enough to the original angle for all practical purposes. The operator need have no concern that any slight deviation from the original angle will adversely affect the accuracy of the lathe since all components treated will be altered proportionately during this complete rescraping job. If an exact duplication of the angle is desired, the information no doubt may be obtained from the manufacturer. With this data, special spotting tools can be made up to duplicate the angle exactly.

Scraping operations are frequently suspended to check for OBJECTIVE NO. 3 An indirect check for this was made in the previous OBJECTIVE. But now we will test specifically for the parallelism of the V-slides in the horizontal plane. Fig. 26.18 shows the simple apparatus required and the set up for the test.

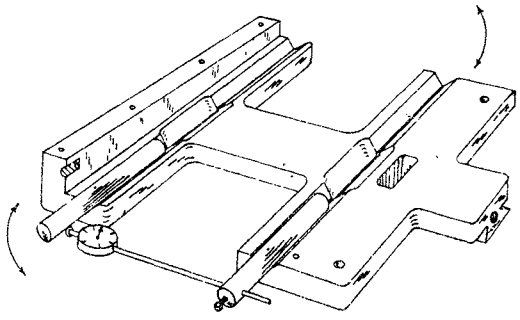

Fig. 26.18 Showing method of checking V-slides of carriage for parallelism in horizontal plane.

Two short, steel cylinders are procured. One cylinder is drilled and tapped. Both are then hardened and precision ground. Their diameter is calculated so that they will make contact with the sloping sides of the V, approximately half way in, as shown in Fig. 26.19. (See Sec. 15.2)

Insert a threaded rod in the tapped cylinder and lock it securely. Fasten a DIAL INDICATOR to the other end of the rod. Adjust the device so that as the cylinder is oscillated, the contact button of the DIAL makes and breaks contact with the stationary cylinder. This test is made on both ends of the carriage as indicated. If a zero-zero reading is observed, OBJECTIVE NO. 3 is satisfied.

We must check at frequent intervals for OBJECTIVE NO. 4. The set up for this is shown in Fig. 26.20 and the tolerance is also indicated. After affixing the compound rest, the compound slide rest assembly is mounted on the carriage and the cross slide tapered gib is inserted and adjusted for sliding pressure. The carriage is placed on a SURFACE PLATE. Then a PRECISION CYLINDER is inserted in the back V-slide of the carriage as it rests on the SURFACE PLATE.

In selecting this CYLINDER, do not choose one so large it makes contact at the edge of the V-slide. Instead it is preferable if the diameter permits lodgment about one half of the distance into the V-slide. (See Fig. 26.19) Another PRECI-

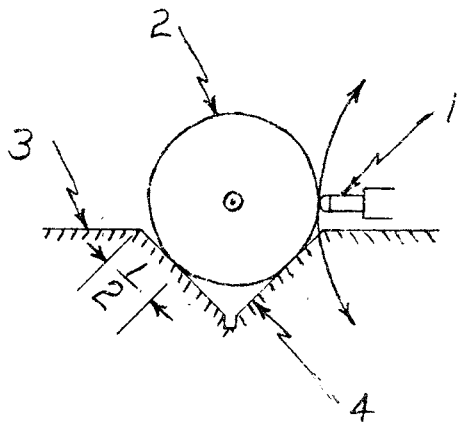

Fig. 26.19 Showing appropriate relationship of cylinder to a Vee when positioned in a slide (or way).

(1) plunger of DIAL INDICATOR (2) precision test cylinder (3) carriage (4) V-slide.

SION CYLINDER may be interposed in the front V-slide to provide stability to the setup.

Referring again to Fig. 26.20, butt a TRY SQUARE against the CYLINDER and position an ANGLE PLATE against the blade of the SQUARE. Under this set up the ANGLE PLATE occupies a position square with the carriage V-slides. After fastening a DIAL INDICATOR to the compound rest, adjust it so that the button is in contact with the ANGLE PLATE. This permits the button to ride across the ANGLE PLATE as the cross slide is advanced.

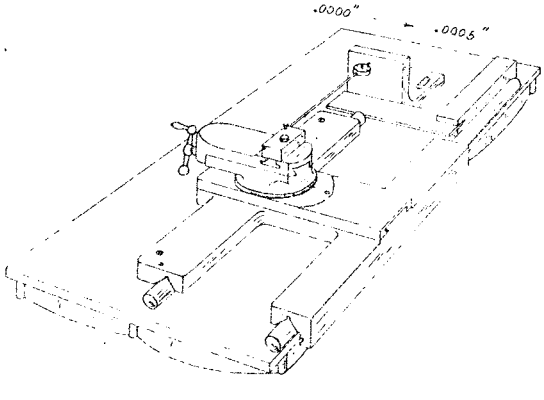

Fig. 26.20 Checking V-slides of carriage to be square with line of travel of cross slide. Tolerance max. .0005" in 6" - High in direction of arrow.

With this arrangement a true indication will still result, whether or not the line of travel of the cross slide parallels the blade of the SQUARE in the vertical plane. This system is preferable to riding the DIAL button directly on the blade because the movement of the cross slide may not be parallel to the SURFACE PLATE due to the set up. By utilizing an ANGLE PLATE, the line of travel of the cross slide in the vertical plane need not be considered and the contact button can ride up or down at will.

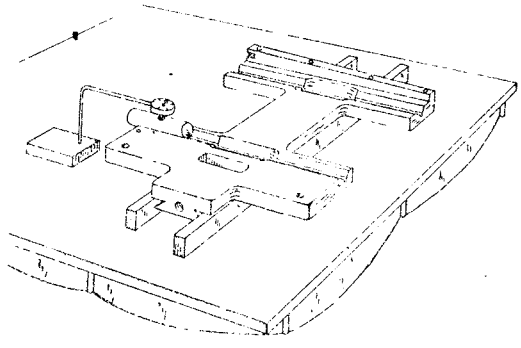

Fig. 26.21 Testing alignment in vertical plane of V-slides of carriage to flat ways of carriage. Flat ways are mounted on PARALLELS.

Fig. 26.21 illustrates the set up to check for OBJECTIVE NO. 5. The flat ways are mounted on identical PARALLELS set on a SURFACE PLATE. A small ground CYLINDER is placed in the V-slide, near the ends of the carriage wings. Measurements are then made with a DIAL INDICATOR from the SURFACE PLATE to the vertical diameter of the CYLINDER. A zero-zero reading at both ends of the wings on both V-slides denotes the requisite accuracy.

The foregoing tests must be made repeatedly and successively until all OBJECTIVES are satisfied simultaneously.

All surfaces of the carriage have now been scrape-finished except for the tapered rear carriage gib bracket bearing shown as (7) in Fig. 26.14. Temporarily delaying completion of this surface, until the bed is scraped, makes possible an easier fitting of the carriage tapered gib which will be utilized in this construction.

Before undertaking to scrape the outer ways of the lathe bed, it must be pointed

out that in the elementary lathe under discussion there are in addition two other bed ways which must also be improved by scraping. These are the inside ways i.e. the back inverted V-way and the front flat way which guide and support the head stock and tail stock. For spotting these ways the base of the tail stock may be used in lieu of a special template. We will, therefore, delay the scraping of the bed until the tail stock base is readied as a template.

Sec. 26.31
The TAILSTOCK BASE as a Spotting Template

Much work can be saved by using the tailstock base as a spotting template for the inverted V-way and flat way of the lathe bed, which for simplicity are referred to as the inside ways of the bed. Fig. 26.22 shows a view of the bottom slides of the tailstock base. The two bearing surfaces are indicated.

Currently we are engaged in preparing the tailstock base as a spotting template and therefore are not concerned about future alignments of this part. However, it might be well to mention briefly that one of the ultimate OBJECTIVES of this component is to have the top surface of the tailstock base (4) level when positioned on the bed ways. This can be accomplished by either of two methods, viz:

First, by making all necessary correction on the top surface of the tailstock when it is treated. This is the plan discussed in the following sequence.

Second, top and bottom surfaces of the tailstock base are scraped parallel while the unit is being prepared as a template. If this course is adopted, the required alignment of levelness is achieved subsequently by scraping the inside ways of the bed.

Neither method possesses any marked superiority over the other. The amount of metal removed to counteract the small misalignment usually found will in either case be slight. In fact, the greater proportion of the metal scraped away will be due to securing other alignments and an acceptable bearing quality.

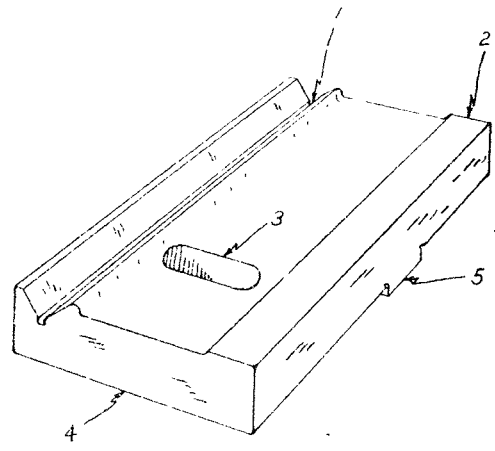

Fig 26.22 View of salient features of tailstock base.

(1) V-slide (2) flat slide (3) slot for clamping bolt (4) top surface (5) transverse way.

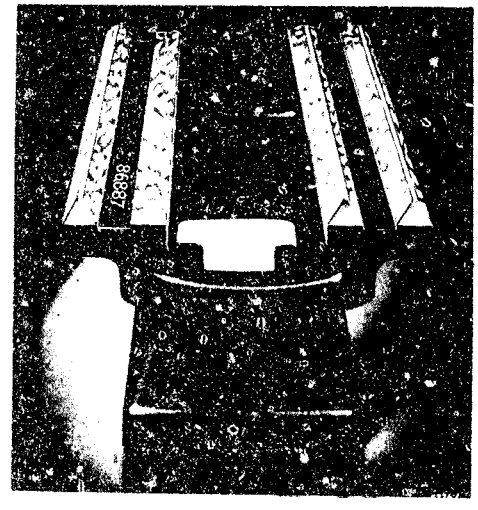

PLATE 23. End view of lathe bed showing bearings consisting of three inverted V-ways and one flat way. (Courtesy - South Bend Lathe Works.)

Sec. 26.32
OBJECTIVES: The SLIDES of the Tail Stock Base

1. To be parallel to the original factory plane.
2. V-slide and flat slide to be parallel in the vertical plane.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

In attaining OBJECTIVE NO. 1 the least worn portions of the inside ways of the lathe bed are selected as spotting surfaces for the slides of the tail stock base. In the elementary lathe used as an example, the area showing the least wear would be that portion of the bed occupied by the head stock. These portions of the ways, due to their protected position, receive no wear or damage.

Lathes that do not have inside ways extending the full length of the bed are somewhat more difficult to treat. The best that can be done in such cases is to locate the portion of the ways showing the minimum deterioration and use it as the spotting surface.

It would not be unduly repetitious to state again that the least worn portion of the ways should always be chosen regardless of the number of dent burrs it may have. The burrs can be removed and the pit marks that remain will not affect the spotting of the tail stock base. On the other hand, a worn area, even if free from burrs, will not provide the close approximation of the original surface that is so desirable and necessary.

After the most suitable areas of the lathe bed ways are selected, they are coated with marking compound. The tail stock base is placed on the bed and its slides spotted, using an exaggerated stroke of about 6 length. Ordinarily, a stroke of this length would be improper under usual spotting conditions. For present purposes, however, a sweeping stroke is ideal because it will produce an average marking on the V-slide and flat slide of the tail stock base. While such a stroke will somewhat blur the outline of the high spots, making their location and size difficult to determine, nonetheless it will provide the necessary evidence of any divergence between the V-slide angle of the tail stock base and the inverted V-way angle of the bed.

Since it is known that the bed ways are not accurate, the operator at this time merely takes cognizance of the coloring of the markings transferred to the tail stock base from the lathe bed ways without using it as a basis for scraping metal. The responsibility for making the surfaces flat and producing a good bearing devolves upon the alternate application of standard tools. An ANGLE STRAIGHT EDGE is suitable for the V-slide and a SURFACE PLATE or STRAIGHT EDGE is appropriate for the flat slide.

As the scraping proceeds, increasing uniformity of the colored markings over the entire V-slide of the tail stock base, indicates that the angle is correct. At the same time, uniformly colored markings over the length and breadth of the flat slide indicate that the improvement of this surface is keeping pace with the V-slide. In short, the markings produced by the spotting action of the bed are mainly for the purpose of determining how closely the two bearing surfaces of the tail stock base match the bed ways. Thus in the final stages of the work, the markings produced by the spotting action of the bed ways are utilized only to keep tabs on the similarity between the V-slide angle and flat slide of the tail stock base on the one hand, and the inverted V-way angle and flat way of the bed, on the other. By proceeding in this manner, OBJECTIVE NO. 1 will be attained.

From time to time, the tail stock base is tested for OBJECTIVE NO. 2, as shown in Fig. 26.23. Place the casting on a work bench. Lay a PRECISION CYLINDER in the V-slide. A DIAL INDICATOR clamped to a PARALLEL is mounted on the flat slide. Adjust the DIAL button to the vertical diameter of the CYLINDER with sufficient pressure to obtain a reading. By sliding the apparatus, readings are taken at both ends of the CYLINDER. Scraping is continued until a zero-zero indication is achieved.

Fig. 26.24 illustrates a more precise test of parallelism between the V-slide and flat slide. The set up requires two PARALLELS to be set under the member and a short length of cylindrical ground stock to be placed at one end of the V-slide. PRECISION GAGE BLOCKS are built up on the flat slide until a PRECISION LEVEL when spanned across the BLOCKS and cyl-

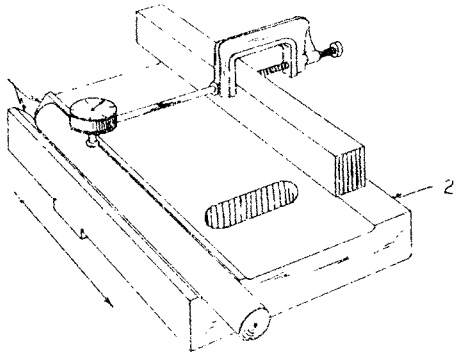

Fig. 26.23 Testing parallelism of flat slide to V-slide in vertical plane.

(1) V-slide (2) flat slide

nder indicates level. The apparatus is moved intact to the opposite end of the member where the test is repeated. Parallelism in the vertical plane is denoted if the bubble centers at both positions.

All OBJECTIVES are attained simultaneously.

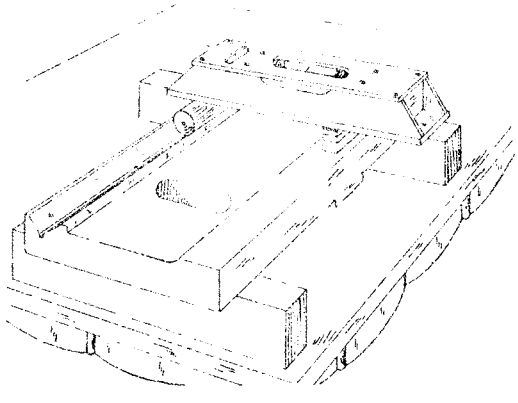

Fig. 26.24 Method of testing V-slide and flat slide for parallelism in vertical plane using a cylinder, precision level, and gage blocks.

The base of the tail stock is now ready to be used as a template to spot the inside ways of the bed. As the reader will recall, the carriage member previously was prepared to serve as the template for the outside ways of the bed. All of this preparatory work was designed to expedite subsequent operations on the lathe bed.

Sec. 26.33
The Bed of the Lathe.

In all types of lathes, the bed is the foundation on which the machine is built. The bed shown in Fig. 26.25 is a casting substantially constructed and rigidly braced

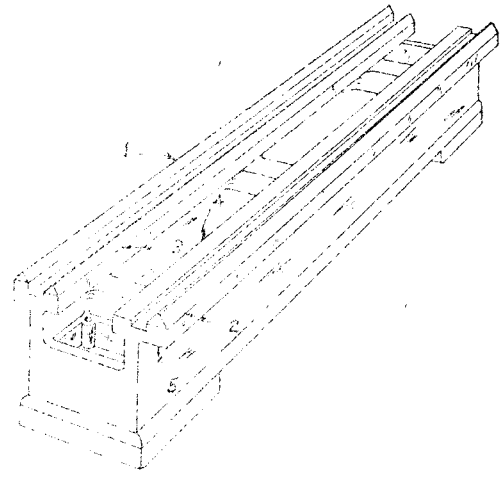

Fig. 26.25 View of bed of lathe with all auxiliary parts removed.

(1) front outside inverted V-way (2) rear outside inverted V-way (3) inside inverted V-way (4) inside flat way (5) rear carriage gib way

It accurately scraped and properly leveled it will provide a precision base for the various members which are bolted to, or slide upon it. Usually the bed casting contains a large percentage of steel. As a consequence the ways are a hard, close grained semi-steel, which has greater strength and wearing qualities, but is more difficult to scrape than ordinary gray cast iron.

Sec. 26.34
The Bearing Surfaces of the Bed.

Several of the more common types of bearing surfaces which machine tool builders incorporate in their designs are shown in cross section in Fig. 26.26. The bearing surfaces of a lathe bed may consist of any one of the types represented in the figure or a combination of severa

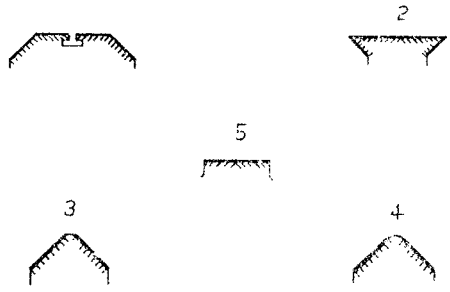

Fig. 26.26 Common types of bearing surfaces on lathe beds. The dimensions of the several bearing surfaces are proportional to each other. Bearing surfaces are double lined.

(1) combination flat and angular way (2) dovetail
(3) inverted V-way - flat non-bearing top
(4) inverted V-way - rounded non-bearing top
(5) flat way

types. These bearing surfaces may be at the same level or at different levels i.e. "stepped". Esentially the bearing surfaces of all lathe beds respond equally

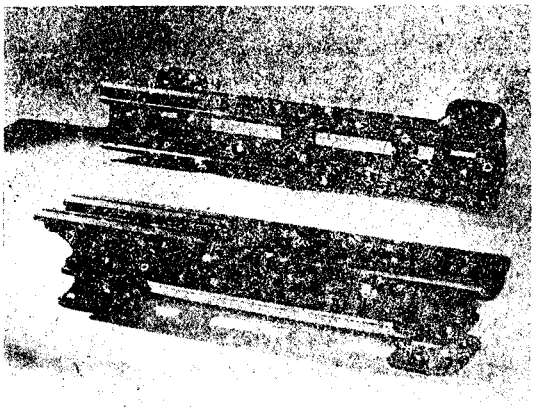

PLATE 24. Close-up of bed of 9-inch swing bench lathe before scraping. (Courtesy - South Bend Lathe Works.)

well to the same general reconditioning procedure. The methods outlined in the following pages are suitable as a basis for such treatment.

Set ups, jig designs and procedures for testing will vary to some extent when beds have types of bearing surfaces different than those shown in Fig. 26.27 which is the form under discussion.

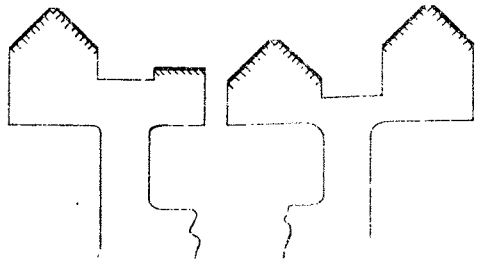

Fig. 26.27 Cross section of bed ways.

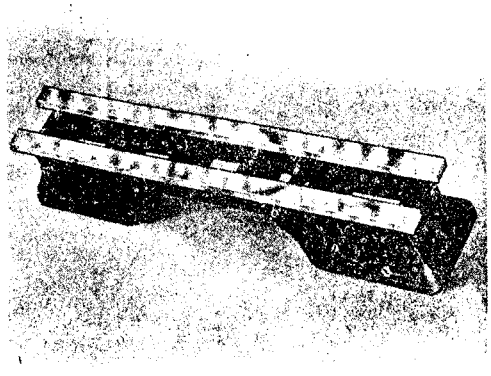

PLATE 25. View of lathe bed characterized by flat ways. (Courtesy - Atlas Press Company)

Sec. 26.35
Reasons for Leveling the Bed

Before proceeding to scrape the ways of the bed this member must be leveled as closely as possible to the plane in which it was scraped and aligned when manufactured. (See Sec. 14.10) There are several important reasons for this requirement, namely:

1. If the lathe bed is set haphazardly on an uneven floor, the bed will immediately be twisted due to the new distribution of weight between the legs. To scrape the ways when the bed is in a distorted position means that an unnecessarily large quantity of metal must be scraped from the bearing surfaces to produce straight and level ways.

2. The excessive amount of metal removed by this procedure will needlessly further misalign other components which are dependent for their position on the bed ways. This makes necessary extensive refitting.
3. Some adjustment of the lead screw, half nuts, and bearings will usually be necessary to compensate for the new alignment resulting from even the minimum amount of scraping. Nonetheless, the failure to level the bed, prior to re-scraping the ways, will necessitate removing an additional thickness of metal therefrom, and will unnecessarily increase the cost of the undertaking. See Note below.

The foregoing explanation should make it apparent why the lathe bed must be leveled accurately prior to any scraping of the ways. The correct step-by-step procedure to accomplish this will be described in the operations which follow:

NOTE:
If the scraper has followed the sequence of operations suggested in Sec. 26.2, the bed will have been leveled before any work is done on the carriage and tail stock members.

Sec. 26.36
Types of Leveling Surfaces on Lathe Beds.

Leveling operations are always conducted from the leveling surfaces. These may be either bearing or non-bearing. Flat ways are bearing surfaces and also are typical leveling surfaces. A non-bearing leveling surface may be an integral part of a way. An example of the latter is the long narrow flat surface on top of the inverted V-way, shown in Fig. 26.25. On some types of inverted V-ways the top may be rounded. One or more kinds of leveling surface may be found on the same lathe bed.

Sec. 26.37
Selection of Leveling Surfaces

In those instances when the leveling surfaces are also bearing surfaces, the least worn, or damaged, areas are selected as locations for the PRECISION LEVEL. This is also done when the leveling surfaces

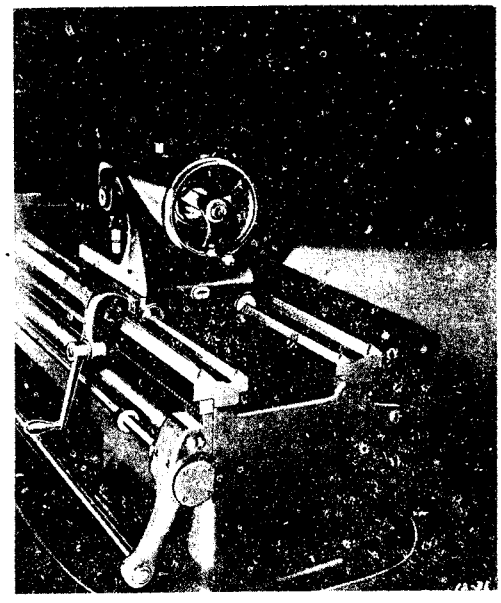

PLATE 26. Close-up of lathe bed having four inverted V-ways. Tailstock is fitted to the inside ways. (Courtesy - The American Tool Works Company)

are non-bearing. In general, if a flat way is available for leveling, it should be used in preference to other types of ways because the condition of the surface is more easily determined. Furthermore, the flat way affords greater stability to the testing instrument.

Sec. 26.38
Leveling the Lathe Bed

The first operation on the lathe bed is to level it in the original position. This means to restore the ways to the plane they were initially aligned by the builder.

There are several factors which make this somewhat difficult to accomplish. In the first place, the bed may have become warped during its period of use. Secondly, the leveling surfaces, if also bearing surfaces, are obviously deteriorated; and if non-bearing, they may be burred or otherwise damaged. In spite of these unfavorable conditions, accuracy requirements can be satisfied if three remedial steps are taken, namely:

1. Remove all dent burrs from the leveling surfaces by filing or scraping. Only the raised portion of the metal is treated.

Do not attempt to deal with pits, scratches etc., and thereby lower the overall plane. With burrs eliminated from the surface it will now be possible for the PRECISION LEVEL to give a true indication of any deviation from the plane established at the time of manufacture.

2. Adjust the bed casting by shimming so that the ways are dead level. This condition is determined by placing the PRECISION LEVEL successively on the leveling surfaces at a number of different locations, in both the transverse and longitudinal directions to obtain an average reading. Meanwhile the legs or frame is shimmed, as required, and the hold down bolts are adjusted to preserve the new alignment.
3. Immediately recondition the leveling surfaces.
   a. If the leveling surfaces are non-bearing, spot and scrape them so that when completed, the PRECISION LEVEL can be laid on them anywhere and in either direction, and register a true indication of the degree of levelness.
   b. If the leveling surfaces are in the category of bearing surfaces levelness should, as a matter of course, be included in the scraper's OBJECTIVES. This condition will then be routinely achieved along with other alignments during the scraping-in process.

In leveling operations on a lathe bed, these few rules are important enough to be stressed, even at the risk of being repititious, namely: Levelness checks should always be made in both directions. When placing the PRECISION LEVEL transversely, it is always set on the leveling surfaces so as to span the two outer ways. If the instrument is not long enough to bridge over the distance, a SCRAPED PARALLEL is put underneath, as shown in Fig. 26.28. The test for levelness transversely is repeated at both ends and in the middle. When checking longitudinally the instrument is laid alternately on the leveling surfaces of both ways in several locations to obtain an average reading.

The reader should also understand that it is necessary to conduct the transverse and longitudinal levelness checks, simultaneously, meanwhile shimming the bed and tightening the hold down bolts. In fact, it is practically impossible to level the lathe bed in one direction and then level it in the other direction. The operations must be performed successively, and repeatedly, until the proper accuracy exists. The tolerance allowed for levelness in lathe bed ways is indicated in Fig. 26.29a & b.

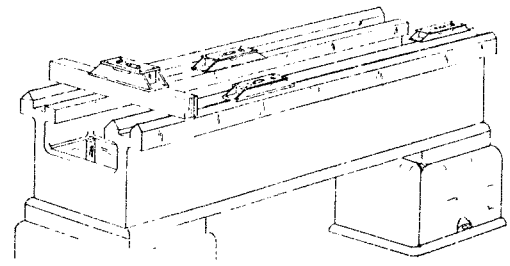

Fig. 26.28 Showing placement of PRECISION LEVELS on leveling surfaces of lathe bed.

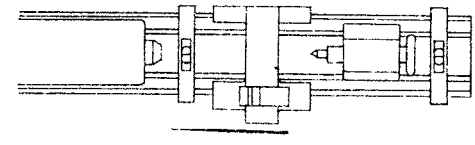

Fig. 26.29(a) Bed level transverse direction. Tolerance max. .0005" - 12".

Shims should be driven under the lathe at the points where the bolts go through the machine into the bench or floor. Then leveling, adjusting the shims, and tightening the hold-down bolts, are conducted in a co-ordinated manner so that when the bed is securely bolted, the bed is leveled as accurately as possible. The operator should spare no efforts to secure accuracy.

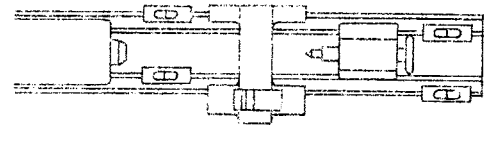

Fig. 26.29(b) Bed level longitudinal direction. Tolerance max. .0005" - 12".

Sec. 26.39
Reconditioning the Leveling Surfaces

When the bed is leveled satisfactorily, the operator should immediately re-condition the non-bearing leveling surfaces. As for the leveling surfaces which are also bearing surfaces, it will be unnecessary to give them special attention at this time because, during the process of scraping them to a correct alignment, they will automatically be made accurate as leveling surfaces. It is the leveling surfaces which are non-bearing that should engage the scraper's immediate attention.

In treating a leveling surface on an inverted V-way having a rounded top, it is advisable to scrape a narrow flat at the apex of the inverted V, running the full length of the bearing. Similar treatment is accorded the leveling surface on an inverted V-way having a flat top. It is only necessary to widen the flat surface a trifle to provide a true and accurate leveling plane extending the length of the bearing.

The reconditioning process consists simply of using a SURFACE PLATE or a STRAIGHT EDGE to spot the leveling surfaces. Then they are scraped until a PRECISION LEVEL placed anywhere on them, transversely or longitudinally, will indicate dead level. By so modifying the leveling surfaces we provide a means whereby quick, accurate leveling of the machine is possible at any future time. This is the principal, if not the only reason, for undertaking this work. Refer to Sec. 14.22 for supplementary reasons.

Now that the lathe bed has been leveled as accurately as possible in its original factory plane, and the non-bearing leveling surfaces re-conditioned, we can begin the actual scraping of the bearing surfaces of the lathe bed.

Sec. 26.40
Scraping the Bed.

The bearing surfaces on the lathe bed are scraped in the same order that they are enumerated, viz:

1. The outside ways, comprising of the front and rear inverted V-ways which guide the carriage.
2. The inside ways, comprising an inverted V-way and a flat way which align and guide the head stock and tail stock.
3. The rear carriage gib way of the bed.

Sec. 26.41
The Datum Point of the Lathe

The two outside inverted V-ways of the lathe bed is the DATUM POINT for the machine as a whole. Generally speaking, all alignments are based on these bearing surfaces.

Sec. 26.42
OBJECTIVES: The OUTSIDE WAYS of the Bed.
(Front & Rear Inverted V-ways)

1. To duplicate the original inverted V-way angle and center to center spacing of the inverted V-ways.
2. To be straight
3. To be level in transverse direction.
4. To be level in longitudinal direction.
5. To be fitted to the V-slides of the carriage with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The front and rear outside inverted V-ways of the lathe bed are the Datum Point of the machine and hence are very important. Due to their importance, the requirements they must satisfy are exacting, making these surfaces difficult to recondition.

Some assistance in spotting operations is afforded by the carriage which has been scraped to template quality. It is advisable, however, to make alternate applications of spotting compound with a STRAIGHT EDGE. This tool should be of a size sufficient to cover the entire length of the ways. Otherwise, the longest one available must be utilized.

When applying a tool of inadequate length, special attention should be given to the recommendations for preventing "wind" discussed in Sec. 9.6. It is not easy to spot the narrow sloping bearing surfaces of the inverted V-ways with a STRAIGHT EDGE so proper manipulation of the tool is necessary if accurate results are to be obtained.

To accomplish OBJECTIVE NO. 1, the outside inverted V-ways of the bed are spotted by using the lathe carriage as the

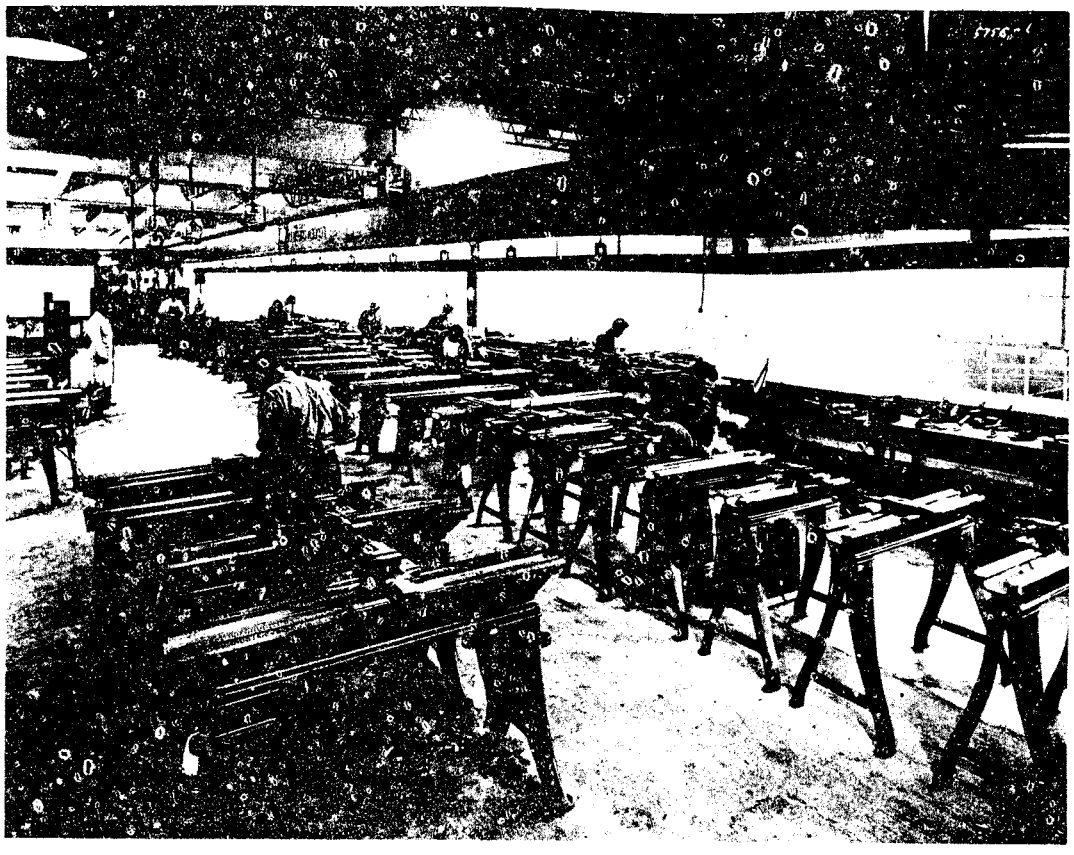

PLATE 27. General view in factory showing men at work scraping the ways of lathe beds. (Courtesy - South Bend Lathe Works.)

spotting tool. A thin film of compound is spread evenly on the outside inverted V-ways of the bed. Next the V-slides of the carriage are carefully cleaned and the member is placed in position. After moving the carriage the entire length of the bed ways a few times, it is removed. The markings on the inverted V-ways are now inspected to learn what is needed to satisfy OBJECTIVE NO. 1.

The spacing is known to be correct when there is a uniform coloration of the markings, on both sides of each inverted V-way. This signifies that equal pressure has been exerted by the weight of the carriage on all four sides of the two prismatic ways. By the same token the original inverted V-way angle is known to be duplicated. (As we have shown in Sec. 26.30, the carriage V-slides have previously been scraped so as to reproduce the original spacing and angle.)

Straightness in the bed ways, specified by OBJECTIVE NO. 2 may be tested by application of the Taut Wire and Microscope system, described in Sec. 22.8. Progress towards OBJECTIVE NO. 2 can be checked also by the alternative method shown in Fig. 26.30. In this set up the carriage is placed on the bed at the tail stock end. Then a PRECISION LEVEL is set lengthwise on top of a PARALLEL which is laid on the carriage flat ways. Notice is taken of the position of the bubble. It should center because the ways and slides of the carriage have already been scraped parallel in the vertical plane. Any deviation of the bubble from center will signify that the axis of the inverted V-ways of bed are not level in the transverse direction. The carriage is pushed carefully along the bed towards the head stock end, stopping at intervals of about 12" to observe if there has been any displacement of the bubble. If none is discernible from end to end, the bed ways are straight.

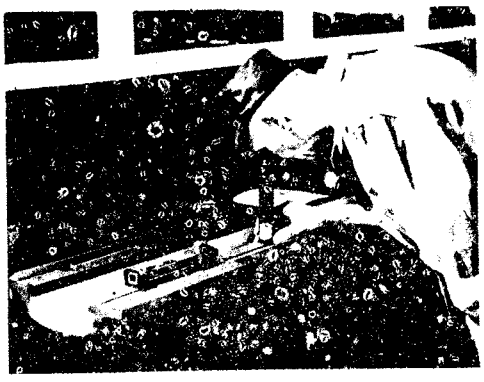

PLATE 28. Inspector examining the scraped surface of a lathe bed with a microscope. (Courtesy - South Bend Lathe Works.)

CAUTION:

Be sure that the PRECISION LEVEL doesn't change position as the carriage is moved.

The foregoing tests are very important because it will be found that "wind" is a condition that very easily insinuates itself in the bed ways of lathes. The longer the ways, the more serious the problem can become. It is a defect that must be continually guarded against. Theoretically, a STRAIGHT EDGE will help to keep the inverted V-way straight but there is still a tendency to develop a twist because of the difficulty in spotting narrow, sloping surfaces with accuracy. This is particularly evident when the tool is shorter than the ways it is applied to.

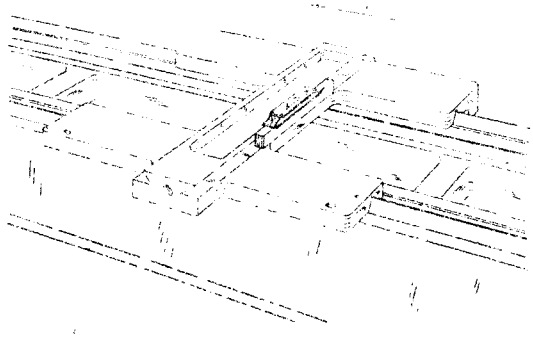

Fig. 26.30 Method of testing for "wind" in ways of bed by using travel of carriage. Displacement of bubble in PRECISION LEVEL indicates a "wind".

The effect of "wind" in the lathe bed is similar to the condition that results when a lathe bed is not properly leveled. Lathe operation is then characterized by inaccurate turning due to the generation of tapers on the work piece. This is caused by non-parallelism of the two outer inverted V-ways. One of the bearings deviates vertically from the other, either in a straight line, or in a slight curve. The markings transferred by either spotting gage i.e. the carriage or the STRAIGHT EDGE, will usually give no indication of this condition, unless it is quite pronounced. Ordinarily, on inverted V-ways it can be detected only by the use of a PRECISION LEVEL, unless a special set up, such as the Wire & Microscope system is arranged. (Sec. 22.8) This condition of "wind" or twist must be corrected because these inverted V-ways are to be the Datum Point, hence must be accurate. For additional information on "wind" the reader is referred to Sec. 22.6.

The alert reader will see that the foregoing set up is equally applicable as a check for OBJECTIVE NO. 3.

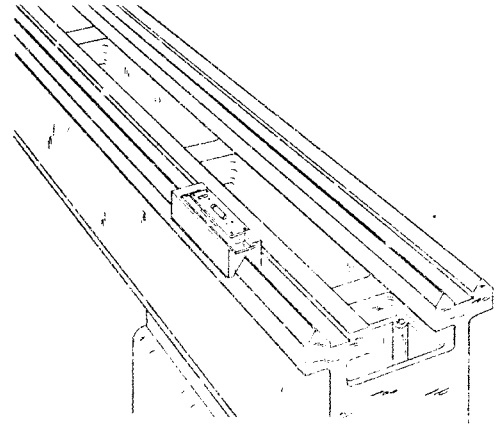

Fig. 26.31 Arrangement for testing levelness of ways of bed in longitudinal direction, using a PRECISION LEVEL on a V-block.

Attainment of OBJECTIVE NO. 4 may be proved by laying the PRECISION LEVEL longitudinally along each bed way in turn and testing for levelness as shown in Fig. 26.31. Since these outer bearings are of the inverted V-type, it will be necessary to interpose a PRECISION V-BLOCK between them and the instrument. The

V-BLOCK, of course, must be scraped to fit.

It will be noted that the PRECISION LEVEL is not placed on the leveling surfaces, which have been previously leveled, but on the bearing surfaces after interposing the PRECISION V-BLOCK. Thus, in effect, we are testing the bearing surfaces for levelness longitudinally.

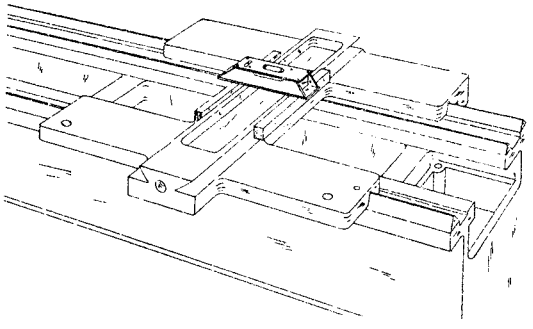

Fig. 26.32 Method of testing levelness of ways of bed in longitudinal direction by means of carriage.

Fig. 26.32 shows an alternative method. After mounting the carriage on the bed ways, an IDENTICAL PARALLEL is placed on each carriage flat way, and a PRECISION LEVEL is spanned across. If the bubble centers and remains so as the carriage is moved from end to end of the bed, levelness in the longitudinal direction is indicated, and OBJECTIVE NO. 4 is achieved. Incidentally, this also confirms the execution of OBJECTIVE NO. 2.

If approved scraping technique is employed, the required surface quality and fit called for by OBJECTIVE NO. 5 is produced simultaneously.

This completes the two outside inverted V-ways. Both ways are now in condition to be used as the DATUM POINT.

NOTE:

It is demonstrable that lathe beds wear more rapidly in the center portion than at the ends. There is, moreover, a static stress at the mid-portion of the ways caused by the weight of the carriage and apron. Furthermore under working pressure, the cutting action of the tool tends to force the front way of the bed downward, while raising up the rear way.

To minimize these influences, some machine tool builders utilize unilateral tolerances so as to oppose this deforming tendency. Two devices are resorted to: First; the front way is made straight, if possible, but is allowed a slight tolerance, convex only. Second, the rear way is made straight but the tolerance, if taken, is concave only.

Since the ways must be scraped-in and aligned, as a pair and not separately, the bed ways are tested transversely at the mid-portion, as well as the ends, with a PRECISION LEVEL. The tolerance allowed in this direction limits the tolerance which is acceptable for each individual way in the longitudinal direction. In short, an average tolerance for the two ways is taken. This prevents cumulative error should the minimum tolerance for convexity of the front way and the maximum tolerance for concavity of the rear way be utilized simultaneously.

Convexity of the front way is indicated when the bubble in the glass moves towards the center of the bed. Concavity of the rear way is disclosed if the bubble moves away from the center of the bed.

Sec. 26.43

OBJECTIVES: The INSIDE WAYS of the Bed.
(Inverted V-way and flat way)

1. To duplicate the original inverted V-way angle.
2. To be parallel to the DATUM POINT (outside inverted V-ways) in the vertical and horizontal planes.
3. To be fitted to the V-slide and flat slide of the tail stock base, with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

In treating the inside ways of the bed, use will be made of the base of the tailstock as a template. The reader will recall that this component was dealt with previously for just such a purpose.

The inverted V-way and flat way are coated with marking medium and spotted by placing the base of the tail stock in position on the ways. (Due to the relatively small size of the template, accurate

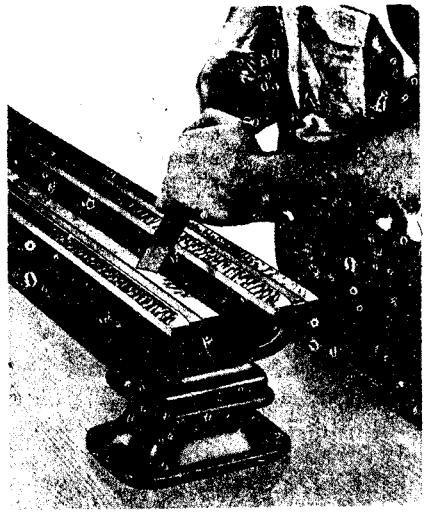

PLATE 29. Close-up of hand scraping the ways on a lathe bed. (Courtesy - South Bend Lathe Works.)

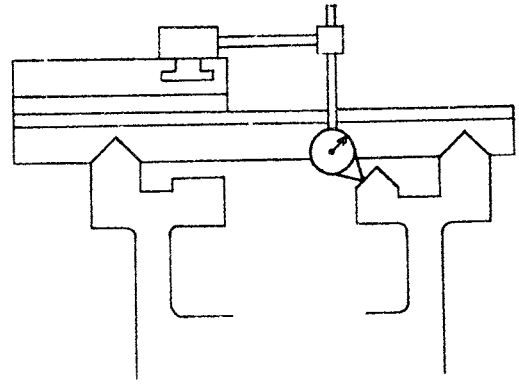

Fig. 26.33 Testing alignment of inside ways of bed.

RECOMMENDED STANDARDS

Tool Room lathes	12" to 18" inc. Engine lathes	20" to 36" inc. Engine lathes
.0005" in 48"	.00075" in 48"	.001" in 48"

(Maximum reading along length of bed)

markings cannot be produced except by spreading the compound on the work surface.) The tail stock is moved by hand, back-and-forth a few times, the full length of the bed ways. After removing the tailstock the inside ways of the bed are scraped in accordance with the markings produced by the spotting action of the template.

This lengthy movement, while counter to the usual spotting practice is justified in the present application. It is not anticipated that the spotting action with this small template will indicate straightness of the ways from end to end. Rather the primary purpose is to disclose the angular value being developed in the inverted V-way and to show how intimately the slides of the tail stock match the mateing ways of the bed i.e. area contact. A STRAIGHT EDGE of appropriate length is applied alternately to develop flatness and straightness over an extended area.

OBJECTIVE NO. 1 is attained when the markings on the flat way and both sides of the inverted V-way have uniform coloration and distribution the entire length of the bed when produced by the spotting action of the tailstock base.

The set up to check OBJECTIVE NO. 2 requires mounting the carriage on the bed ways and attaching a DIAL INDICATOR to the carriage. The contact button of the DIAL is adjusted to touch one sloping side of the inverted V-way being tested. Then the carriage is moved the entire length of the bed meanwhile noting any change in the reading of the DIAL. Next the other inclined side of the inverted V-way is tested in the same manner. Finally, the flat way is checked. The tolerance shown in Fig. 26.33 must not be exceeded in any case.

Additionally, the PRECISION LEVEL is set crosswise from time to time, on the bed flat way. It is desirable to keep this surface horizontal so that when the machine is placed in operation, wear will be uniform on both ways.

Scraping is continued until all OBJECTIVES are satisfied.

Sec. 26.44
The Rear Carriage Gib Way of the Bed.

The major bearing surfaces of the lathe bed have now been completed and we can turn our attention to the rear carriage gib way of the bed, shown as (5) in Fig. 26.34. This surface is used as a hold-down bearing surface for the carriage and is situated directly under the rear inverted V-way of the bed. On some lathes the rear carriage gib way of the bed is in direct bearing contact with the gib bracket (7) bolted to the rear carriage gib bracket bearing represented by (6) in Fig. 26.39. This clamping strip (gib

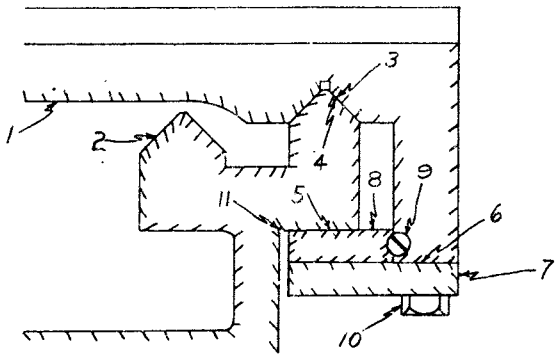

Fig. 26.34 Cross sectional view of assembled parts of carriage positioned on bed ways.

(1) carriage (2) inside inverted V-way of bed (3) V-slide of carriage (4) rear inverted V-way of bed (5) rear carriage gib way of bed (6) rear carriage gib bracket bearing (7) rear carriage gib bracket (8) tapered gib piece (9) adjusting screw for tapered gib (10) hold down bolt for bracket (11) groove

bracket) is adjustable for sliding pressure.

On other types of lathes a loosely fitting or closely fitted gib is inserted between the gib bracket and the bed. Fig. 26.38 and Fig. 26.36 show an example of each.

From a study of these illustrations it can be seen that this surface (rear carriage gib way) must be parallel with the line of travel of the carriage, otherwise either binding or looseness may affect the accuracy of the cut.

In the manufacturing process this surface is very accurately machined thereby

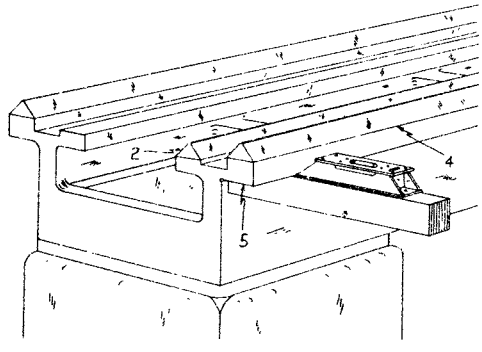

Fig. 26.35 View showing method of testing rear carriage gib way of bed for levelness.

(2) inside V-way of bed (4) rear inverted V-way of bed (5) rear carriage gib way of bed

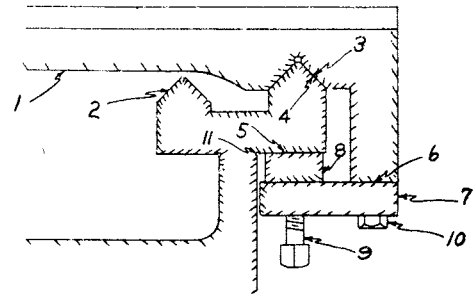

Fig. 26.36 Showing application of closely fitting flat gib to fasten carriage to bed of lathe.

(1) carriage (2) inside inverted V-way of bed (3) V-slide of carriage (4) rear inverted V-way of bed (5) rear carriage gib way of bed (6) rear carriage gib bracket bearing (7) rear carriage gib bracket (8) tightly fitting flat gib (9) adjusting screw for gib tension (10) hold down bolt or clamping bolt for bracket (11) groove

making it parallel to the bearing surfaces. Usually it is not scraped after machining because further finishing is deemed unnecessary. However, on a reconditioning job, when this surface is badly worn or warped, it is necessary to scrape it.

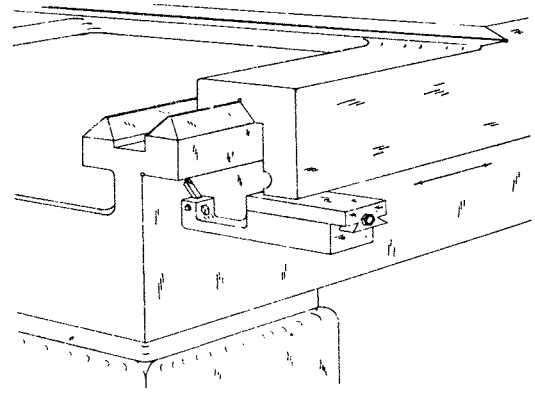

Fig. 26.37 General arrangement for machining gib way of bed parallel with ways of bed.

Sec. 26.45

OBJECTIVES: The REAR CARRIAGE GIB WAY of the Bed.

1. To be parallel in the vertical plane to the DATUM POINT i.e. the outer inverted V-ways.
2. To be level in the transverse direction.
3. To have a surface quality of 5 - 15 bearing spots per square inch.

PROCEDURE:

For spotting this underneath surface, an ANGLE STRAIGHT EDGE will probably have to be used due to space limitations. One which will span the entire length of the gib way is preferable. A shorter tool simplifies the handling problem but the correct spotting procedure becomes more difficult and accuracy is impaired.

Preparation for checking OBJECTIVE NO. 1 is made by placing the carriage in position on the bed ways. A DIAL INDICATOR is then mounted on the carriage and the DIAL button is set in contact with the gib way of bed. The carriage is moved from end to end of the bed. A zero-zero reading is desirable but a tolerance similar to that shown in Fig. 26.33 is permitted.

Proximity to OBJECTIVE NO. 2 is ascertained by holding a PARALLEL against the rear carriage gib way and mounting a PRECISION LEVEL upon it, as shown in Fig. 26.35. Additional tests for levelness are made in the transverse direction at several points from end to end of the surface.

The rear carriage gib way of the bed is a very difficult surface to scrape due to its position. Therefore, the operator should be acquainted with every possible short cut. In this connection, if too much effort and time would be involved in getting the bubble centered i.e. the surface leveled, work should be continued only until a flat bearing is obtained. (This will be very close to levelness in the transverse direction anyway.) When this surface is checked, still referring to Fig. 26.35, the degree of deviation from levelness should be recorded, as well as a note made of the direction that the surface tapers. Having this information it is then possible, in due course, to scrape the rear carriage gib bracket bearing (6) Fig. 26.34 and Fig. 26.36, so that it tapers in the same direction and by an equal amount.

When this procedure is followed, the gib (tapered gib - Fig. 26.34 or closely fitting straight flat gib - Fig. 26.36) which ties the carriage to the bed will be more easily fitted since the two surfaces it bears against will be parallel in the transverse direction. A review of Sec. 17.16 on tapered gibs and Sec. 17.7 on closely fitting straight flat gibs should prove helpful.

In the constructions shown in Fig. 26.38 and Fig. 26.39 the gib way need only be flat. Whether or not it has a transverse tilt is immaterial.

To make scraping easier and spotting more accurate, it is advisable to provide a groove (11) if one is not already prepared.

OBJECTIVE NO. 3 is attained simultaneously. Finishing this surface completes the scraping of the lathe bed.

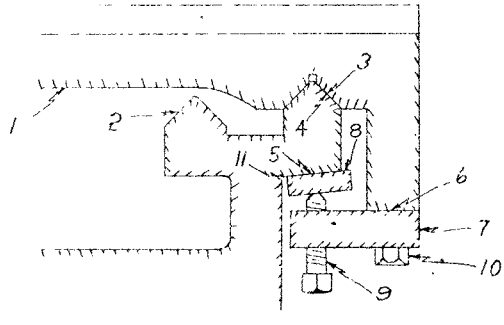

Fig. 26.38 Showing application of a loose fitting flat gib in fastening carriage to ways of bed.

(1) carriage (2) inside inverted V-way of bed (3) V-slide of carriage (4) rear inverted V-way of bed (5) rear carriage gib way of bed (6) rear carriage gib bracket bearing (7) rear carriage gib bracket (8) loose fitting flat gib (9) adjusting screw for flat gib (10) hold down bolt for bracket (11) groove

NOTE:

It is impractical, except on the smaller bench lathes, to invert the bed in order to situate the rear carriage gib way (5) Fig. 26.34 on top. As a result, all spotting and scraping operations must be performed while the surface is in an awkward position. Needless to say, this makes it a tedious and back breaking job.

When a considerable quantity of metal must be removed from the rear carriage gib way of the bed because of warping etc., it sometimes pays to mount on the carriage a cutting tool designed to feed across the gib way of the bed in the transverse direction. The travel of the carriage along the bed ways is then used to plane this surface, as shown in Fig. 26.37. By taking light cuts, moving the carriage by hand, most of the rear carriage gib

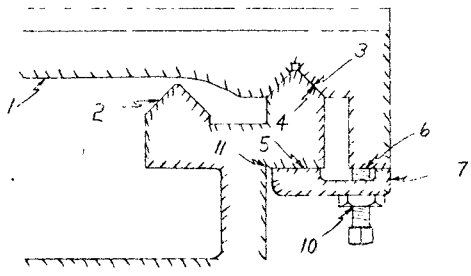

Fig. 26.39 Diagram of gib bracket bearing acting as a gib.

(1) carriage (2) inside inverted V-way of bed (3) V-slide of carriage (4) rear inverted V-way of bed (5) rear carriage gib way of bed (6) rear carriage gib bracket bearing (7) rear carriage gib bracket (10) adjusting screw for bracket · (11) groove

way of the bed is easily and automatically machined parallel to the outer inverted V-ways of the bed, in the longitudinal direction. If the in-feed of the cutting tool is properly aligned, the gib way will also be machined level in the transverse direction. This practice saves valuable time and much hand labor, besides producing an acceptable finish.

A hand sanding disc grinder, carefully applied, can also be used to speed the work when a large amount of metal must be removed.

Sec. 26.46
The REAR CARRIAGE GIB BRACKET BEARING

The rear carriage gib bracket bearing (6) Fig. 26.34 is the last surface of the carriage to be scraped. It is standard practice to postpone work on it until after the rear carriage gib way of the bed (5) is completed. The latter surface is so difficult to scrape, due to its position, that ordinary common sense suggests finishing it before turning to the more accessible rear carriage gib bracket bearing.

Ordinarily, all of the carriage surfaces are scraped in regular order, with the exception of this one, which is completed only after the bed is finished. In other words, this method is adopted because it allows the operator to scrape the rear carriage gib bracket bearing to conform to any variation from levelness in the transverse direction that may develop in the rear carriage gib way of bed.

In the scraping procedure described in the section following, the OBJECTIVES listed are formulated on the assumption that the carriage gib piece which is to be used will be either a tapered gib, or a close fitting straight flat gib. The requirements for each class differ as will be noted.

However, if the gib selected for joining the two members is a loosely fitting flat gib Fig. 26.38, or in case the gib bracket itself (7) Fig. 26.39 is to be used in place of a gib, then no critical alignment is required of this surface. Scraping may then be dispensed with, except in so far as it is necessary to eliminate burrs, or a possible warp from the surface. Under these conditions it would even be feasible to treat this surface at the same time as the carriage slides and ways.

NOTE:
A loosely fitting flat gib is one having ample room to accomodate itself i.e. sufficient space or clearance to tilt and thus make full contact with the rear carriage gib way of bed.

Sec. 26.47
OBJECTIVES: The REAR CARRIAGE GIB BRACKET BEARING

1. To be parallel to the axes of the V-slides of the carriage in the vertical plane.
   (Applies only if a close fitting straight flat gib is used.)
2. To taper with respect to the axes of the V-slides of the carriage in the vertical plane.
   (Applies only with a tapered gib)
3. To be parallel in the vertical plane to the rear carriage gib way of the bed, measured transversely.
   (Applies for both a close fitting straight flat gib and a tapered gib.)
4. To have a surface quality of 4 - 5 bearing spots per square inch.

PROCEDURE:

Since the rear carriage gib bracket bearing is a narrow surface it can be spotted most conveniently with a STRAIGHT EDGE. From now on, the manner of its treatment and the selection

of OBJECTIVES depends upon the choice of gib piece to be attached.

Example No. 1

If a close fitting straight flat gib is to be inserted, it is necessary to scrape this surface parallel to the V-slides of the carriage, measured in the longitudinal direction, and parallel to the rear carriage gibway of the bed, measured in the transverse direction. To this end, two checks must be conducted, consecutively, viz:

1. To check the deviation from parallelism measured in the transverse direction, as required by OBJECTIVE NO. 3, mount the flat ways of the carriage dovetails on PARALLELS. A SURFACE PLATE, which is itself leveled, supports the set up. Placing the PRECISION LEVEL on the rear carriage gib bracket bearing, as represented in Fig. 26.40 take a reading and compare it with that obtained on the gib way of the lathe bed, as in Fig. 26.35. Scraping is continued until the two surfaces are parallel, measured in the transverse direction. As an alternative, mount the carriage on the bed and test the gib bracket bearing (6) and the rear carriage gib way of bed (5) with a PRECISION LEVEL. Then compare the results. The accompanying illustration, Fig. 26.41, will make the operation clearer.

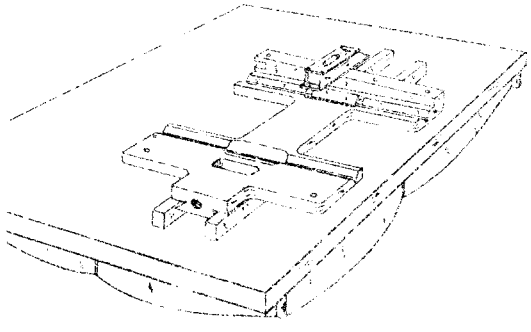

Fig. 26.40 Showing method of using PRECISION LEVEL to test gib bracket bearing of carriage for parallelism with rear carriage gib way of bed.

2. To check parallelism measured in the longitudinal direction, as specified by OBJECTIVE NO. 1, perhaps the simplest of several possible methods is to place the carriage on the bed. Then affix a DIAL INDICATOR to a Surface Gage and set it against the rear carriage gib way of bed. Adjust the contact button to ride against the rear carriage gib bracket bearing. Now either move the carriage along the bed, or if it is more convenient, slide the Surface Gage and attached DIAL INDICATOR along the rear carriage gib way of bed, and note the readings at both ends of carriage.

The two checks described should be alternated. Scraping is continued until a zero-zero reading is obtained. This denotes that OBJECTIVE NO. 1 and OBJECTIVE NO. 3 are satisfied. Incidentally, the bearing quality, as specified in OBJECTIVE NO. 4 should be achieved simultaneously.

Example No. 2

When a tapered gib is to be used, the principal attention given the rear carriage gib bracket bearing is devoted to eliminating any taper in the transverse direction with respect to the rear carriage gib way of the bed. Substantially, this is what OBJECTIVE NO. 3 signifies. Consequently, only the first part of the preceding test for parallelism needs to be applied.

The elimination of the transverse taper is desirable to provide ease of fitting and permanence of position for the tapered gib, as was the case with the preceding example.

When transverse taper cannot be detected, OBJECTIVE NO. 3 is satisfied.

With this form of gib OBJECTIVE NO. 2 is not critical. However, if there is any likelihood of salvaging and reusing the old gib piece, the original taper on the rear carriage gib bracket bearing should be maintained. Otherwise any chance taper that evolves in the course of fulfilling OBJECTIVE NO. 3, will prove satisfactory. The new tapered gib piece will then be measured to fit the changed circumstances.

As in the previous example, the surface quality required by OBJECTIVE NO. 4 is attained simultaneously.

NOTE.

Some lathes have carriages which are

gibbed to the bed at two or even three positions, such as at the front, rear, and middle (if the carriage has three slides.) Thus the lathe bed may have one, two, or three gibways and the carriage will have an equivalent number of gib bracket bearings. In all cases, each gib bracket bearing of the carriage is aligned to the gib way of the bed with which it is associated. Treatment is the same whether there is one surface or several.

Sec. 26.48
OBJECTIVES: The GIB PIECE of the Carriage

PROCEDURE:

The method of handling the gib piece will vary according to the type of gib piece employed, for example:

Selection No. 1
The Closely Fitting Straight Flat Gib.

After placing the carriage on the lathe bed, the rear carriage gib bracket (7) Fig. 26.36 is bolted to the rear carriage gib bracket bearing. The distance between the rear carriage gib way of bed and the gib bracket is measured and a straight flat gib is made up. It is ground to fit, that is to say, ground to a thickness just sufficient to slide between the two surfaces. With this gib, provision must be made for holes for the adjusting screws which hold the gib piece in position during operation. To locate the holes properly, the gib is inserted, correctly positioned, and spotted by tightening the adjusting screws. Shallow holes are drilled at the points indicated by the screw pressures.

Selection No. 2
The Tapered Gib.

Unlike the gib piece mentioned above, the tapered gib must be hand scraped as it is fitted. The straight side which is in contact with the gib bracket of the carriage needs only about 4 - 5 bearing spots per square inch. The tapered side which is in sliding contact with the gib way of the bed requires 10 - 15 bearing spots per square inch. It would be repetitious to describe again the procedure for making the tapered gib. The reader is referred to Sec. 17.16 where this subject is dealt with in detail.

Sec. 26.49
The TAIL STOCK of the LATHE

The tailstock of the lathe is a member having longitudinal adjustment on the inside ways of the bed. It can be locked in any position by tightening the clamping bolts provided. This component is composed of two separate units which are described briefly as follows:

1. The tailstock top is adjustable on the base in the transverse direction. It supports the tailstock spindle, or ram.

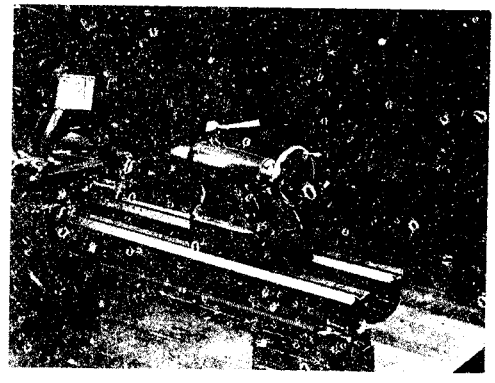

PLATE 30. Close-up of tailstock mounted on ways of lathe bed. (Courtesy - South Bend Lathe Works.)

2. The tailstock base slides on the bed ways. Its top surface is featured by a transverse way. The function of the latter is to guide the tailstock top when moving the dead center laterally off center for taper work, or to adjust for correct alignment with the head stock spindle.

Sec. 26.50
The Tail Stock Top

The tailstock top has only one surface that requires scraping i.e. the bottom surface, shown in Fig. 26.42. This bottom surface slides on, and is in contact with, the top surface of the tail stock base.

The bottom surface is distinguished by the clamping bolt hole (2) and the transverse slide (3) same figure. The latter

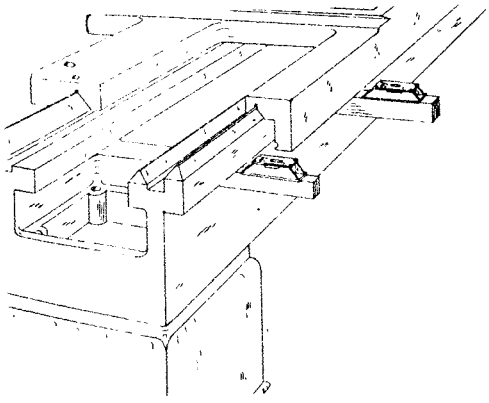

Fig. 26.41 Testing parallelism of rear carriage gib way of bed with rear carriage gib bracket bearing in transverse direction.

feature is not scraped and is a tight sliding fit to the transverse way of the top surface of the tailstock base. Since little movement, except occasional adjustments, occurs between the transverse slide and way, wear will be imperceptible and the slide should need no attention.

An important element of this member is the retractable spindle, or ram, shown as (4) in Fig. 26.43. It must be in good condition and a nice sliding fit in its housing (5) same figure. Otherwise, under pressure of a cut, or weight of a piece of work, it will shift, destroying the accuracy of the tail stock alignment.

To determine how perfectly the spindle fits its housing a simple but effective test can be made. Fasten a DIAL INDICATOR adjacent to the spindle so that the button of the instrument makes contact at the vertical diameter. Apply manual pressure to

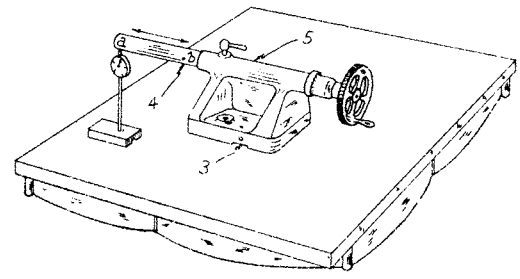

Fig. 26.43 Showing method of testing bottom surface of tailstock top for parallelism with axis of ram. Measurements at "a" and "b" should be identical.

(3) transverse slide (4) ram (5) housing

the spindle in the vertical plane and note the movement of the DIAL hand. Repeat the procedure in the horizontal direction.

In either case, if deflection of the pointer exceeds a small percent of the alignment tolerance of the ram, (See Fig. 26.50 and Fig. 26.51) repair is necessitated before any scraping can even be considered for the tail stock surface. If treatment calls for reboring the tail stock for a new and larger spindle, the axis of the new hole must satisfy, as closely as possible, two conditions, viz:

First, it must be square with the transverse slide (3) of the tailstock top.

Second, it must be parallel in the vertical plane with the bottom surface of the tailstock top.

Since this corrective work is a machining operation, the procedure to be followed belongs more properly to a book on machine methods, It will, therefore, not be discussed further.

The demonstration of how to handle this member will be expedited if, in our imagi-

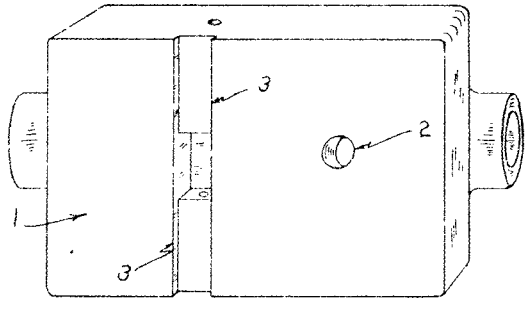

Fig. 26.42 View of bottom surface of tailstock top.

(1) bottom surface (2) clamping bolt hole
(3) transverse slide

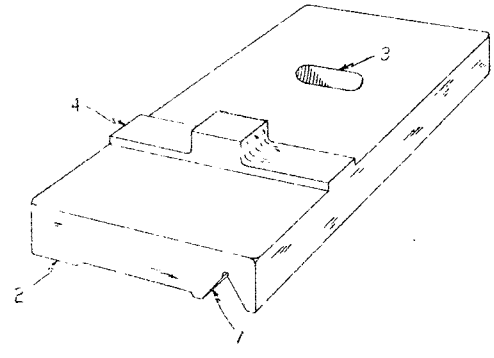

Fig. 26.44 View of base of tailstock.

(1) V-slide (2) flat slide (3) slot for clamping bolt (4) transverse way

nary case, we assume that the tailstock spindle and housing are in good condition. The problem initially confronting us will be to scrape the bottom surface of the tailstock top to a correct alignment with the axis of the spindle.

Sec. 26.51
OBJECTIVES: The BOTTOM SURFACE of the Tailstock Top

1. To be parallel to the axis of the ram in the vertical plane.
2. To be parallel with the original factory plane.
3. To have a surface quality of 5 - 15 bearing spots per square inch.

PROCEDURE:

The scraping operation on the bottom surface of the tailstock top is a relatively simple one. Spotting for its part, can be most easily performed with a SURFACE PLATE.

To check for OBJECTIVE NO. 1 the tailstock top is laid on a SURFACE PLATE with the bottom surface in contact. The tailstock spindle is then extended and clamped. By the way, all alignment tests involving the tailstock spindle are conducted with this member clamped. Clamping stress will always influence the position of the ram.

Next, using a Surface Gage and attached DIAL INDICATOR, measurements are taken at both extremities of the ram on the vertical diameter, as for example at (a) and (b) in the set up shown in Fig. 26.43. When a zero-zero reading is obtained at both positions, the bottom surface is parallel with the axis of the ram, fulfilling OBJECTIVE NO. 1. Scraping should be continued until this condition is achieved.

If removal of metal is executed "straight down" a surface is produced that is parallel with the original factory plane, satisfying OBJECTIVE NO. 2.

CAUTION:
Exercise care in scraping along the edges of the transverse slide (3).

With the attainment of all three OBJECTIVES, simultaneously, the tailstock top is completed.

Sec. 26.52
The Tailstock Base

This unit consists of three surfaces which are scraped. They are enumerated as follows:

1. The V-slide
2. The flat slide
3. The top surface

The underneath bearing surfaces were shown in Fig. 26.??. Fig. 26.44 illustrates the top surface.

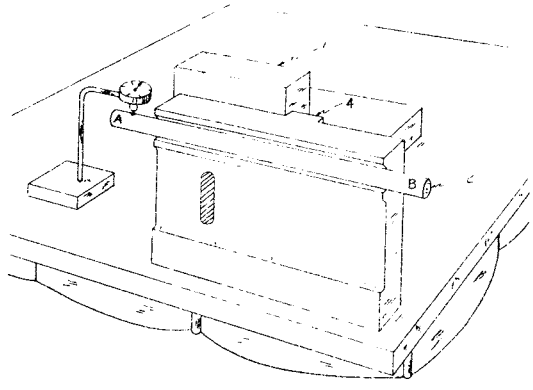

Fig. 26.45 Method of testing V-slide of tailstock base to be square with transverse way.
(1) angle plate (2) cylinder (4) transverse way

As the reader will no doubt recall, the V-slide and the flat slide have already been scraped and prepared as a template for spotting the inside ways of the bed. Some minor adjustments may now be necessary to convert the tailstock base from its present status as a mere template, to its proper and ultimate function as an integral part of the lathe. That in brief is the purpose of the next series of operations.

Sec. 26.53
OBJECTIVES: The V-SLIDE and FLAT SLIDE of the Tailstock Base.

1. V-slide to be square with transverse way on the top surface.
2. V-slide and flat slide to be parallel, in the vertical plane.
3. To be fitted to the bed ways with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

Both surfaces should be dealt with together. The best plan is to coat the inside ways of the bed with marking compound and employ these bearing surfaces as a template to spot the slides of the tailstock base. Supplementary spotting with an ANGLE STRAIGHT EDGE is acceptable.

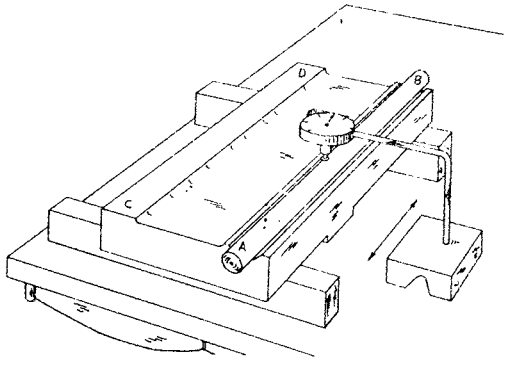

Fig. 26.46 General arrangement of apparatus for checking V-slide and flat slide for parallelism measured in the vertical plane. Proper alignment is indicated when measurement at (A-B) is zero-zero and measurement at (C-D) is also zero-zero.

Fig. 26.45 shows the set up to test for OBJECTIVE NO. 1. The transverse way of the base is bucked against a PRECISION ANGLE PLATE positioned on a SURFACE PLATE. A PRECISION CYLINDER is held in the V-slide. A DIAL INDICATOR button is adjusted to touch on the vertical diameter at point (A) and then moved to point (B). When a zero-zero reading is noticed, the V-slide satisfies OBJECTIVE NO. 1. Scraping is continued until this alignment is achieved.

OBJECTIVE NO. 2 may be checked with the apparatus represented previously in Fig. 26.23 and Fig. 26.24. It would only be repetitious to describe the set up in detail again.

All three OBJECTIVES are accomplished simultaneously.

Sec. 26.54

OBJECTIVES: The TOP SURFACE of the TAILSTOCK BASE

1. To be parallel to slides of tailstock base in the vertical plane, measured in the longitudinal direction.
2. To be level transversely when in position on the bed ways.
3. To have a surface quality of 5 - 10 bearing spots per square inch.

PROCEDURE:

Before discussing methods a few general remarks are in order. The top surface of the tailstock base, shown in Fig. 26.44 is a bearing surface, although in the strict sense of the word, not a sliding bearing. A momentary sliding movement occurs only when the tail stock top is moved transversely on the top surface of the tailstock base for taper turning, or trued for proper alignment with the axis of the headstock spindle.

Due to the infrequent adjustment of the member, the wear on this surface is negligible. Consequently, a light scraping may be all that is necessary to dispose of some trifling burrs. Thus, OBJECTIVE NO. 3 is easily attained.

However, if the casting is warped, and this is often the case, considerable metal may have to be removed to obtain a flat surface. The casting is subjected to considerable strain by the clamping bolt and such pressure is bound to impair the part, sooner or later.

A brief inspection of the top surface of the tailstock base shown in Fig. 26.44, discloses that it is a flat plane, divided by an obstruction. The operator in searching for a convenient means of spotting it might assume that the bottom surface of the tailstock top can be used as a template. However, such is not always the case. If so used, the markings produced by such a spotting may be inaccurate because the member is often a tight sliding fit in the transverse way of the tailstock base. Therefore, the procedure recommended is to make up a special template which will spot the entire top surface simultaneously.

In scraping the top surface of the tailstock base, care must be observed that the sides of the transverse way (4) are not disturbed or altered lest it lead to a sloppy fit with the top member and cause mis-alignment. To repeat, the sides of the transverse way are never scraped.

OBJECTIVE NO. 1 may be tested as shown in Fig. 26.46. After mounting the base on two IDENTICAL PARALLELS set on a SURFACE PLATE, a PRECISION

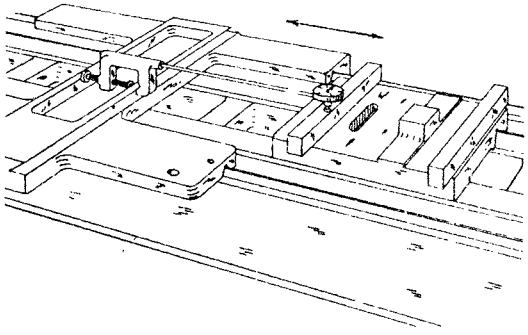

Fig. 26.47 Testing parallelism of top surface of tailstock base to ways of bed. (longitudinal direction)

CYLINDER is laid in the V-slide. Then a DIAL INDICATOR is utilized to test from the SURFACE PLATE to the PRECISION CYLINDER. A zero-zero reading is desired at points (A) and (B). The flat slide is also measured, readings being taken at points (C) and (D).

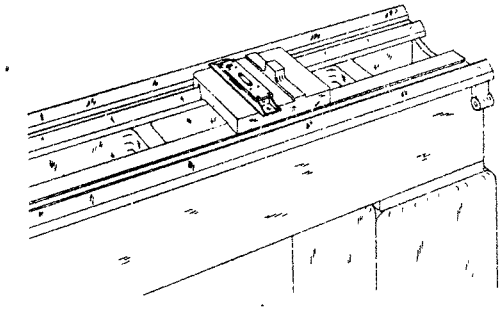

Fig. 26.48 Checking tailstock base for levelness transversely.

Another possible method, represented in Fig. 26.47, requires placing the carriage and the tailstock base on their respective ways on the lathe bed. PRECISION PARALLELS of equal height are laid crosswise on the base, as shown. After mounting a DIAL INDICATOR on the carriage, the button is brought in contact with the nearest PARALLEL. To actuate the DIAL and obtain a reading the carriage is moved back and forth. By advancing the carriage, the button can be brought in contact with the second PARALLEL where another reading is taken. An identical reading on each PARALLEL signifies OBJECTIVE NO. 1 is attained.

OBJECTIVE NO. 2 is tested by placing the tailstock base on the lathe ways and laying a PRECISION LEVEL transversely across the base, as shown in Fig. 26.48. The bubble must center.

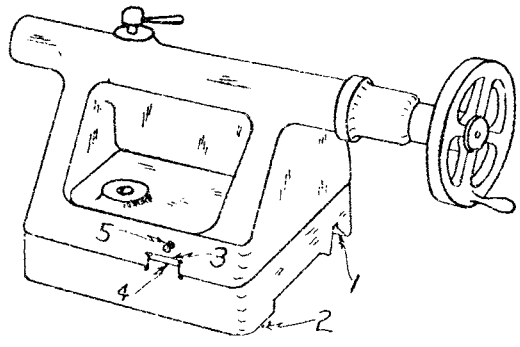

Fig. 26.49 Diagram of assembled tailstock showing clearance between transverse slide and transverse way.

(1) V-slide (2) flat slide (3) transverse slide (4) transverse way (5) set over screw

Scraping is continued until all three OBJECTIVES are fulfilled.

The next operation involves the FINAL ALIGNMENT of the tailstock to the bed.

Sec. 26.55

OBJECTIVES: The FINAL ALIGNMENT of the TAILSTOCK to the Bed.

1. Axis of the tailstock spindle to be parallel to the outer inverted V-ways of the bed in the horizontal and vertical planes.
2. Slides to be fitted to the bed ways with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

In preparation for this final alignment, the tailstock top and the tailstock base are assembled and placed on the bed of the lathe. Make certain, when the two parts are placed together, that the bottom surface of the tailstock top is in full contact with the top surface of the tailstock base. In short, see to it that the transverse slide (3) Fig. 26.49, does not bottom on the transverse way (4). A feeler introduced between the two members at this point will detect any interference.

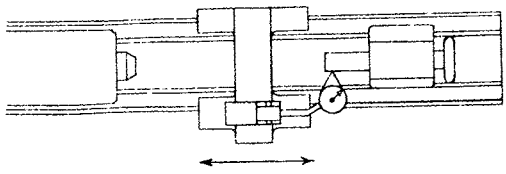

Fig. 26.50 Final alignment of tailstock spindle to bed ways in horizontal plane.

RECOMMENDED STANDARDS

Tool Room lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathes
0 to .0005"	0 to .0005"	0 to .0005"

(Forward at end of spindle when fully extended)

It makes no difference where the tailstock is placed on the ways for these operations, since the bed should now be in perfect condition. Ordinarily, one part of the bed ways is used as the position from which to conduct the alignment tests. Another portion is coated with compound and utilized as a spotting template. This practice increases speed because much clean up time is eliminated.

Two consecutive tests are conducted in attaining OBJECTIVE NO. 1. Both utilize the line of travel of the carriage along the bed ways as the medium whereby the axis of the tailstock spindle is tested for parallelism with the outer inverted V-ways of the bed.

To expedite the work, the apron is attached to the carriage. It takes but a few minutes, and then the handwheel may be used to move the member. This procedure is preferable to pushing the carriage by hand, because both the speed of traverse and the stopping point are more accurately controlled. (It is unnecessary to mount the lead screw to attach the apron.)

The first test consists of checking whether the axis of the fully extended tailstock spindle is parallel to the outside inverted V-ways of the bed in the horizontal plane. To conduct the survey a DIAL INDICATOR is mounted on the carriage, or more specifically, on the compound slide rest because this member is provided with a T-slot to which a suitable fixture may be conveniently bolted. The DIAL INDICATOR is positioned to bear against the near side of the extended spindle at the horizontal diameter. (The tailstock spindle is clamped in the fully extended position.) To obtain a reading, the carriage is moved along the bed ways. The alignment of the tailstock spindle in the horizontal plane is considered acceptable if the unilateral tolerance indicated in Fig. 26.51 is not exceeded.

The second test consists of checking whether the axis of the fully extended tailstock spindle is parallel to the outer inverted V-ways of the bed, in the vertical plane. The spindle remains in the same fully extended position occupied for the previous test, but now the DIAL INDICATOR is adjusted so as to ride the top of the spindle at the vertical diameter. By moving the carriage on the inverted V-ways of the bed another reading can be taken. The alignment of the tailstock spindle in the vertical plane is acceptable if the unilateral tolerance shown in Fig. 26.51 is not exceeded.

In the recommended standards of both tests, working pressure is a factor. For example, in testing horizontally, it is the pressure of the tool against the work during a cut which must be taken into account. When testing vertically, it is the weight of the work piece for which allowance is made. If the unilateral tolerance is exceeded in either test, then the V-slide (1) and the flat slide (2) of the tailstock shown in Fig. 26.44 must be scraped so that the new alignment will conform to the tolerances given.

After determining the amount of error and its direction, the tailstock is removed to the portion of the bed ways reserved for spotting purposes. In doing this, the member must not be slid. Instead, it should be lifted and then placed carefully on the coated portion of the ways. Transfer of the film is made in the usual manner.

Scraping is most efficiently performed at a work bench. Before beginning this operation, a little reflection should enable the operator to determine how to scrape the tailstock V-slide so as to "throw" the axis of the spindle in the proper direction, thereby correcting the error disclosed in the two tests. The amount of metal to be removed from the tailstock slides at this time should be slight, since all the OBJECTIVES, previously prescribed for these surfaces, have been designed so that only a light touching up would be necessary during the Final Alignment.

During the initial stages of testing, the tailstock may simply be placed in position on the bed. But in the final stages, it should be clamped to the bed so that the tests will be conducted under circumstances similar to actual operating conditions.

This concludes the scraping operations on the tailstock member, although two additional tests must be conducted with the spindle before the member can be accepted for use.

Sec. 26.56
The Tailstock Spindle Taper Hole Alignment.

Briefly, the purpose of the following tests is to make certain that the tapered spindle hole has been properly machined, reamed, or ground so that the axis of the tapered hole is "in-line" with the axis of the lathe, or more specifically, "in-line" with the axis of the tailstock spindle.

To prove the accuracy of the alignment of the tapered hole in the tailstock spindle, two tests are conducted consecutively. Strictly speaking, the following tests do not concern scraping operations, but they are, nonetheless, vital to the successful alignment of this lathe member. When the accuracy of the tapered hole falls below the recommended standards, the tailstock spindle hole must be reworked, or a new spindle inserted.

Preliminary to conducting these tests it is necessary to make up a test bar. The bar is made of steel, hardened and accurately ground to fit the tapered hole in the spindle. It should have a straight portion of suitable length, usually 12". On some lathes, the test bar prepared for the tailstock can be used later on for the headstock, provided the tapered hole is identical in both members. When it is dissimilar, a separate bar is required for each member.

CAUTION:
It is not good practice to "bush" a test bar in order to adapt it to a larger hole.

Having prepared the bar, insert it into the tapered hole in the spindle. Make certain that the contacting surfaces are perfectly clean. Foreign matter may prevent the two tapers from seating accurately and this leads invariably to unreliable readings. It is also obvious that the two tapers must be identical. For additional information on this point, refer to Sec. 15.4.

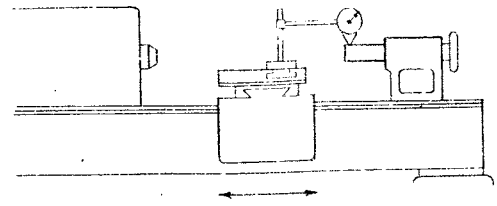

Fig. 26.51 Final alignment of tailstock spindle to bed ways in vertical plane.

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathes
0 to .0005"	0 to .0008"	0 to .0015"

(High at end of spindle when fully extended)

The first test, diagrammed in Fig. 26.52 determines if the axis of the tapered hole in the spindle is "in-line" with the axis of the tailstock spindle in the horizontal plane. A DIAL INDICATOR is mounted on the carriage and adjusted against the near side of the test bar at the horizontal diameter. A reading is taken, as the carriage is moved forward. If the plus or minus tolerance shown in the Figure is not exceeded, the axis of the tapered hole in the spindle, is correctly aligned to the axis of the spindle in the horizontal plane.

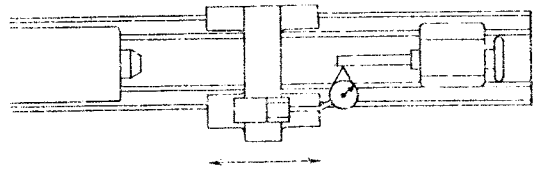

Fig. 26.52 Alignment of taper hole of tailstock in horizontal plane.

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathes
0 to (±) .0005"	0 to (±) .0008"	0 to (±) .0015"

(At end of 12 inch test bar)

The next test which is diagrammed in Fig. 26.53 discloses if the axis of the

tapered hole in the spindle is "in-line" with the axis of the spindle in the vertical plane. The only change required for the set up in this test from the previous one, is to locate the DIAL button at the top of the test bar at the vertical diameter. A reading is taken as the carriage is traversed. If the unilateral tolerance indicated in the recommended standards is not exceeded, then the axis of the tapered hole is "in-line" with the axis of the spindle in the vertical plane.

In case the two tests show that the tapered hole is inaccurate and exceeds the limits allowed, the spindle must be removed from the tailstock. It must then be replaced with a new and accurate spindle. In lieu of this, the tapered hole of the defective spindle can be reworked. However, since this matter pertains to machine shop practice it will not be further discussed.

To reassure the critical reader, it will be emphasized that, finding a tailstock spindle with a defective tapered hole will not affect the alignment of the previously scraped bearing surfaces of the tailstock. Replacement of the spindle or reboring the taper hole will, however, be called for.

Sec. 26.57
The Head Stock of the Lathe

The fixed member of the lathe which carries the work spindle supporting the live center, and the necessary mechanism to drive the work, is called the head stock. It is a solid one piece casting, as shown in Fig. 26.54. The member has two bearing surfaces which are scraped, namely:

1. The V-slide
2. The flat slide

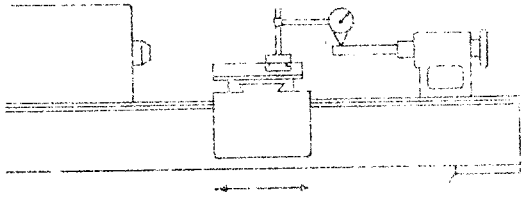

Fig. 26.53 Alignment of taper hole of tailstock in vertical plane.

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 16" inc. Engine Lathes	20" to 30" inc. Engine Lathes
0 to .0005"	0 to .0008"	0 to .001"

(High at end of 12 inch test bar)

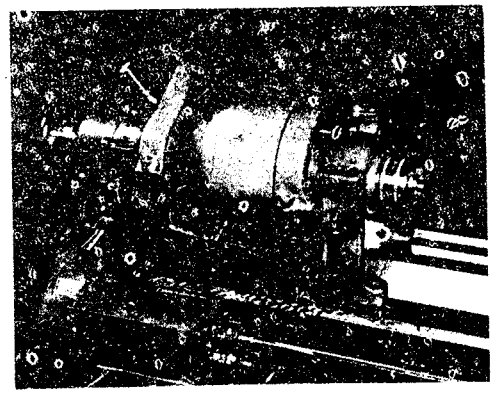

PLATE 31. Close-up of lathe headstock mounted on ways of bed. (Courtesy - South Bend Lathe Works.)

All spotting of this member is performed using the bed ways as a template. However, before any scraping or alignment is attempted, the spindle of the head stock must be given a series of accuracy tests.

Sec. 26.58
Accuracy Tests on the Headstock Spindle

These tests are designed to learn the condition of certain important features of the headstock spindle. Strictly speaking, the check-ups are not the duty or concern of the scraping operator, but for his own information and protection, he should conduct them. It is very possible that, if the spindle cannot pass one or more of these accuracy tests, it is so inaccurate that consistent readings could not be obtained, if the actual alignment procedures, accompanying the scraping operations, were to be executed.

Four accuracy tests are made on the spindle and will be described briefly. Obviously, they are not all of the examinations which the spindle would undergo during a manufacturing process, but they do constitute the indispensable ones which the scraping operator can perform conveniently and in a short time. The checks may be conducted with the headstock placed either on the lathe bed, or perhaps on a work bench.

Sec. 26.59
Spindle Center Runout (1st test)

PROCEDURE:

The test is begun by inserting a perfectly finished, live center into the tapered hole of the headstock spindle. The contact point of a DIAL INDICATOR is placed midway on the top of the 60^0 point of the live center. The spindle center runout is checked by revolving the spindle slowly.

This test will supply information on a number of matters, among them the correctness of the taper in the spindle; possible presence of burrs in the tapered hole; and concentricity of the axis of the tapered hole to the axis of the spindle. The tolerance shown in Fig. 26.55 cannot be exceeded.

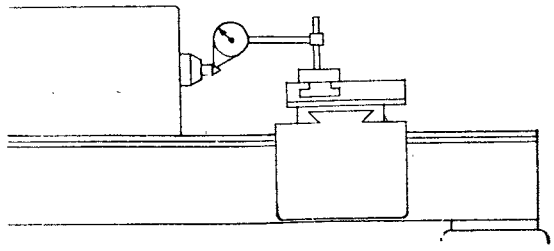

Fig. 26.55 Spindle center run out.

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathes
(Total indicator reading)		
0 to .0004"	0 to .0005"	0 to .00075"

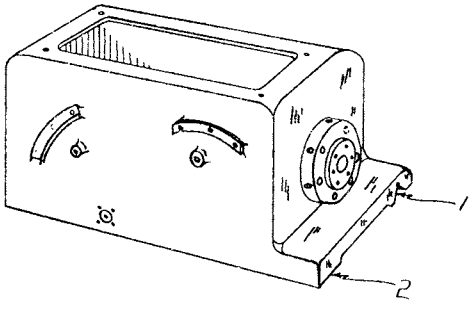

Fig. 26.54 View of the head stock of lathe
(1) V-slide (2) flat slide

Sec. 26.60
Spindle Nose Runout (2nd test)

PROCEDURE:

In this test the DIAL INDICATOR is positioned on the nose of the headstock spindle as shown in Fig. 26.56. The actual position it should occupy, whether directly on the nose, or indirectly, by attaching an accurate test plate, will depend upon the type of chuck mounting used, i.e. threaded, taper, or cam lock.

This test will check the concentricity of the nose with the axis of the spindle. Any error noted must be within the limits of the tolerance.

Sec. 26.61
Cam Action of Spindle (3rd test)

PROCEDURE:

The cam action of the spindle is determined in the following manner. An accurately machined test plate similar in design to the back plate of a chuck is attached. The DIAL INDICATOR button is positioned on the rear side of the test plate, as shown in Fig. 26.57. The tolerance is also indicated. For supplementary material on Cam Action refer to Sec. 16.11.

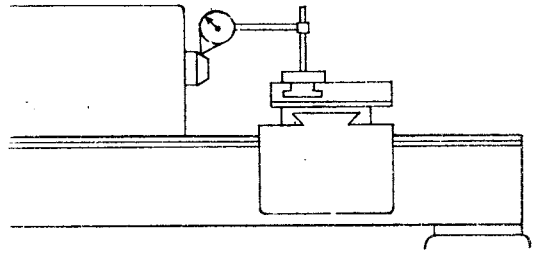

Fig. 26.56 Spindle nose run out

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathes
(Total indicator reading)		
0 to .0003"	0 to .0004"	0 to .0006"

Having ascertained the accuracy of the spindle, the next step is to check the headstock spindle tapered hole.

PLATE 32. Inspector testing alignment of headstock spindle with test bar inserted in tapered hole. Readings are taken from DIAL INDICATOR mounted in lathe tool post. (Courtesy - South Bend Lathe Works.)

Sec. 26.62
Spindle Taper Runout (4th test)

There is a double purpose in conducting this test, namely:

1. To assure that the test bar is properly seated in the tapered hole of the spindle. It is necessary to know this so that readings obtained subsequently in aligning the headstock may be depended upon. In other words, the operator must be certain that the test bar when seated contributes no error to the readings which is not accounted for. (See Sec. 15.7 Sag in Test Bars)
2. To check the concentricity of the taper hole with the spindle axis. Incidentally, the concentricity is more accurately gaged by this set-up than by the test for Spindle Center Runout, due to the greater extension of the test bar.

We will now prepare the necessary apparatus for checking these two conditions.

A test bar is made up with a taper on one end to fit the tapered hole in the spindle. In making the bar, the straight portion should be proportioned to the size of the lathe and therefore will vary in length and diameter.

Before the bar is to be used its accuracy should be verified by mounting between centers and testing for concentricity. (See Sec. 15.11)

Next the bar is inserted into the tapered hole of the spindle. After mounting a DIAL INDICATOR on the carriage, the button is brought to bear against the test bar at say the vertical diameter. As the spindle is slowly revolved, readings are taken at both ends of the bar in turn. The readings obtained must be within the limits permitted, as indicated in Fig. 26.58. If this is accomplished, the test bar is known to be accurately seated in the spindle tapered hole.

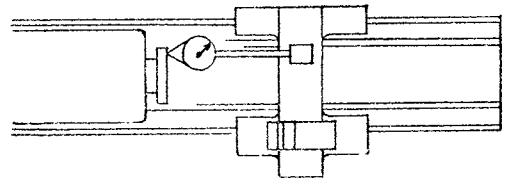

Fig. 26.57 Cam action of spindle

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathes
(Total indicator reading with instrument on rear side of test plate)		
0 to .0003"	0 to .0005"	0 to .00075"

Difficulty in accomplishing a zero-zero reading may be traced to grit or dust particles adhering to the surfaces. The safe practice is to clean the tapered hole with a cloth and stick. Never insert a finger in a revolving spindle.

As to the second consideration, the tapered hole must also be concentric with the axis of the spindle, within the tolerance indicated in Fig. 26.58. If the tolerance is exceeded there are several possible causes therefor.

To fix responsibility, the tapered section of the test bar should be examined to determine if the taper matches the spindle hole. This operation is easily performed by spreading a thin film of marking compound in a narrow streak, lengthwise on the tapered portion of the bar. By inserting the bar in the spindle hole and wringing it, some of the compound is transferred. Examination of the bar after

removing it will reveal if the streak is now spread uniformly around the entire tapered portion of the bar. This procedure will also disclose the presence of burrs, if any, in the spindle hole.

As the test bar is known to be accurate following the test between centers, and since faulty seating due to grit has been eliminated as a cause by careful cleaning, then possibly a non-uniform marking signifies that the tapered hole in the spindle may be affected by out of roundness, burrs, worn areas etc. Correcting this would, of course, entail a machining operation.

Having eliminated both the tapered hole and the test bar as possible factors of error, the operator may proceed with the headstock alignment tests. There is now assurance that the readings obtained henceforth will represent only the actual amount of misalignment of the headstock to the bed ways.

RECAPITULATION:

The purpose of the four tests just concluded, is to demonstrate the accuracy of the headstock spindle. The findings must show that any inaccuracy present in the spindle does not exceed the tolerances permitted in the several tests. If the tolerances are exceeded in one or more cases, the spindle should be reworked by grinding or machining, until it is capable of passing all four tests. The procedure to be followed in reworking the spindle is outside the scope of this book and will, therefore, not be discussed.

Sec. 26.63
Alignment Tests Conducted on the HEADSTOCK SPINDLE.

Three alignment tests will now be conducted on the headstock spindle. They have for their purpose the alignment of the headstock.

OBJECTIVES: Alignment of HEADSTOCK to the Bed.

1. Axis of the headstock spindle to be parallel to the outside ways of the bed in the vertical and horizontal planes.
2. Axis of the headstock spindle to be aligned with the axis of the tailstock spindle, in the vertical plane.
3. Slides to be fitted to the bed ways with a surface quality of 10 - 15 bearing spots per square inch.

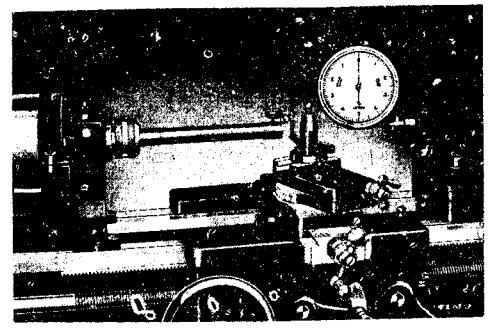

PLATE 33. Close-up showing application of DIAL INDICATOR for testing alignment of headstock spindle in vertical plane. (Courtesy - South Bend Lathe Works.)

PROCEDURE:

We will now by a series of tests determine approximately the degree of misalignment between the axis of headstock spindle and 1) DATUM PLANE and 2) axis of tailstock spindle. Apropos to this the headstock can, in the early stages of testing, be set on the bed without clamping. The final tests, though, should be conducted with it bolted solidly in position to obtain maximum precision.

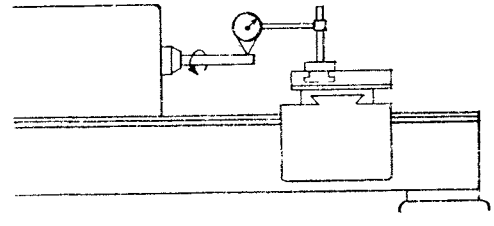

Fig. 26.58 Spindle taper run out.

RECOMMENDED STANDARDS

Tool Room Lathe	12" to 18" inc. Engine Lathe	20" to 36" inc. Engine Lathe
(Total indicator reading at end of 12" test Bar)		
0 to .0006"	0 to .0008"	0 to .00125"
(At end of spindle nose)		
0 to .0003"	0 to .0004"	0 to .0006"

Before performing the preliminary check for OBJECTIVE NO. 1 in the vertical plane, as shown in Fig. 26.59, a

spindle taper runout test is conducted. This requires the test bar to be inserted into the headstock spindle. Incidentally, a runout test must be performed each and every time the test bar is removed and re-inserted to prove the truth of the seating. To nullify the effect of eccentricity error, the mean position is located at the vertical diameter for this portion of the test.

Now returning to the alignment we will mount a DIAL INDICATOR on the carriage. The button of the instrument is placed at the vertical diameter of the test bar. Next the carriage is moved and a reading is taken between the spindle nose and the free end of the test bar. The amount of misalignment of the spindle to the bed ways in the vertical plane is thereby noted. This information relates to the first portion of OBJECTIVE NO. 1.

A similar preliminary check for OBJECTIVE NO. 1 in the horizontal plane is also necessary. This requires finding the mean position of the test bar and turning it to the horizontal plane. Then the button of the instrument is set at the near side of the test bar i.e. the horizontal diameter, as shown in Fig. 26.60. Again the carriage is traversed and the reading is recorded.

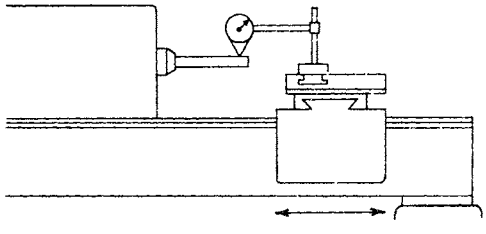

Fig. 26.59 Alignment of head stock spindle in vertical plane.

RECOMMENDED STANDARDS

Tool Room Lathe	12" to 18" inc. Engine Lathe	20" to 36" inc. Engine Lathe
0 to .0005"	0 to .001"	0 to .001"

(high at end of 12" test bar)

These two tests will provide necessary information as to the degree of misalignment now existent in the headstock spindle with respect to the DATUM PLANE i.e. the outside inverted V-ways of the bed. This data refers only to OBJECTIVE NO. 1.

Inasmuch as all three OBJECTIVES must be attained simultaneously, it is important to know at this stage, before any scraping is attempted on the headstock slides, the approximate misalignment in the vertical plane of the headstock spindle with respect to the axis of the tailstock spindle. Since the headstock surfaces have not as yet been treated, it is obvious that the axis of the headstock spindle is higher from the bed ways than the axis of the tailstock spindle, which member has been scrape-finished. We determine approximately how much metal to remove from the headstock V-slide and flat slide by executing the following procedure:

Sec. 26.64
Vertical Alignment of HEAD &TAIL CENTERS

The necessary equipment for this operation includes a test bar of a different type than those previously used. A hardened steel cylinder of suitable length, centered at both ends and then accurately ground to one appropriate overall diameter will be required. It will be mounted between the lathe centers during the test.

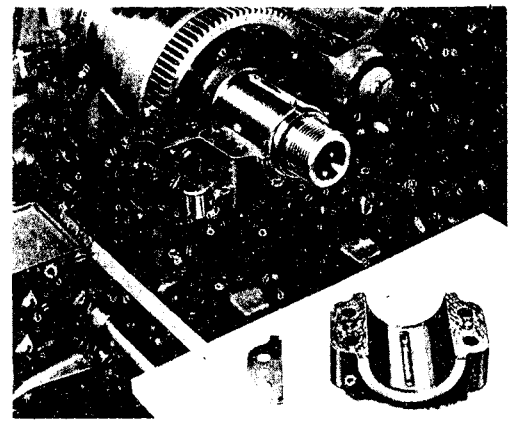

PLATE 34. Close-up of headstock with spindle bearing cap removed to show how surface of headstock and bearing cap are hand scraped and fitted together. (Courtesy - South Bend Lathe Works.)

To facilitate the test for vertical alignment it is necessary to adjust, as closely as possible, the axis of the tailstock spindle in-line with the axis of the headstock spindle in the horizontal plane. The preliminary adjustment is accomplished by the following set up:

After fastening a DIAL INDICATOR to the carriage the contact button is

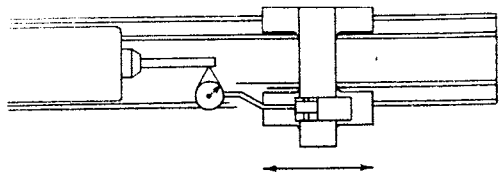

Fig. 26.60 Alignment of head stock spindle in horizontal plane.

RECOMMENDED STANDARDS

Tool Room Lathe	12" to 18" inc. Engine Lathe *	20" to 36" inc. Engine Lathe
0 to (±) .0003"	0 to (±) .0005"	0 to (±) .0008"

(At end of 12 inch test bar)

placed on the horizontal diameter of the test bar, as shown in Fig. 26.61. The carriage is now moved so that the button slides from end to end of the bar. At the same time the tailstock top is set-over on its transverse way until a reading close to zero-zero is attained. We say "close" because at this stage we would not obtain an identical calibration in traversing the test bar from end to end due to the fact that the axis of the headstock spindle is higher than the axis of the tailstock spindle. The reason, as previously stated, is that no scraping has yet been done on the slides of the headstock. Consequently, the DIAL INDICATOR button would ride up or down from the horizontal axis of the test bar as the carriage is moved along the bed ways.

Having adjusted the bar closely, we can proceed to check the vertical alignment. To this end the DIAL INDICATOR is positioned on the vertical diameter of the test bar, as shown in Fig. 26.62. Readings are now taken as the carriage is moved along the bed. The results of this test indicate approximately how much metal must be scraped from the bearing surfaces of the headstock to obtain correct alignment and satisfy OBJECTIVE NO. 2.

After the approximate amount of required correction is learned from this series of tests, spotting and scraping

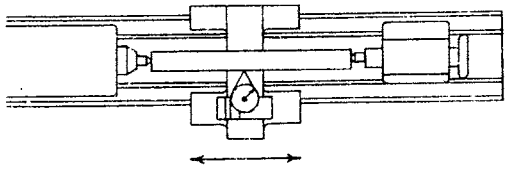

Fig. 26.61 Set up utilized to adjust headstock and tailstock centers in horizontal plane.

operations can be initiated. The headstock is placed carefully on that portion of the bed ways previously coated with marking compound. Then after spotting, the member is removed from the bed and laid on a work bench where it is scraped. Since it is unlikely that a single cycle of spotting and scraping will accomplish the alignments specified in OBJECTIVES NO. 1 and NO. 2, it will be necessary to repeat the foregoing series of tests a number of times. As the alignment approaches the required accuracy, the adjustment of the tailstock in the horizontal plane will be progressively smaller. The need for it will end when the DIAL INDICATOR reading nears zero-zero on both the horizontal and vertical diameters.

When the tests disclose that the correct alignment is imminent, the desired bearing quality is worked into the headstock V-slide and flat slide, to satisfy OBJECTIVE NO. 3. Refer to Sec. 23.25. Simultaneous Achievement of Bearing Quality.

If the tolerances indicated in the tests above mentioned, are not exceeded in the final alignment of the headstock spindle, then the three OBJECTIVES are satisfied and the headstock member is considered completed. However, if during the course of trying to obtain the OBJECTIVES, the scraper should remove too much metal from the slides, thus lowering the axis of the headstock spindle below the axis of the tailstock spindle, it is obvious that OBJECTIVE NO. 2 cannot be satisfied.

Faced with this dilemma, the scraper should continue scraping until OBJECTIVES NO. 1 and NO. 3 are achieved at which moment the headstock is adjudged completed. OBJECTIVE NO. 2 is disregarded.

The matter of the vertical alignment cannot, however, be dismissed. Rectification, in such cases, is obtained by returning to the tailstock. The slides of this member must be reworked, to satisfy all the OBJECTIVES listed in Sec. 26.55, plus this additional one, viz:

"Axis of tailstock spindle to be aligned to axis of headstock spindle in the vertical plane."

When these objectives are satisfied then both of the members are correctly aligned, to each other and to the bed ways. Thus the accuracy of the lathe is in nowise impaired by failure or inability to achieve alignment by means of the headstock.

The correct alignment can still be obtained by reworking the slides of the tailstock.

There is an alternative method of checking the alignment of the axis of headstock spindle to axis of tailstock spindle in vertical plane, as specified in OBJECTIVE NO. 2. The principal advantage of this system is that alignment of the axes of the two centers in the horizontal plane is not required. Another advantage in substituting it is that checking the alignment after each scraping cycle can be done more speedily. A further advantage of the method is that the exact degree of misalignment can be ascertained, not just the approximate amount.

The necessary apparatus for applying the method includes a DIAL INDICATOR mounted on the cross-slide on the carriage. Two precision ground test bars of identical diameter and length are also used. One is inserted in the spindle of headstock, the other is inserted in spindle of tailstock. Both bars are given their usual tests for proper seating, runout etc. Then the button of the DIAL is adjusted to the vertical diameter of each bar at the free end in turn. This can be done without changing the setting of the instrument by moving the cross-slide out and in. Readings are taken which, if within the tolerance allowed, signify that the axis of both spindles are truly aligned in the vertical plane.

NOTE:

During the course of aligning other components of the lathe, the movable members will many times be slid back and forth on the ways of the bed. This causes isolated high spots which previously escaped notice to become sharply defined. Therefore, when all alignments have been completed on the other members, it is good practice to give the bed ways a final touching up to improve the wearing quality, that is, to make it more lasting. (Refer to Sec. 19.12)

Bronze Bearings in Spindles

As a general rule, the slides of the lathe headstock do not wear or warp since the member is bolted solidly to the bed. Consequently, treatment of these surfaces is necessary only for alignment purposes. That is, as the discussion in Sec. 26.63 and Sec. 26.64 has shown, the axis of the headstock spindle must be parallel horizontally and vertically to the bed ways and in-line with the axis of the tailstock.

If the headstock spindle has bronze bearings it is practicable to secure these essential alignments by scraping the round bronze bearing instead of the flat slides. This operation is performed with the head stock bolted to the bed ways. Scraping is done with a round-scraper. The several alignment tests are executed periodically.

Sec. 26.65
Final Alignment of the Carriage Ways

The OBJECTIVES which were sought in scraping the compound slide rest and the carriage were designed so that the member would be correctly aligned to the headstock spindle. How exactly the work was done will be determined by the following alignment test.

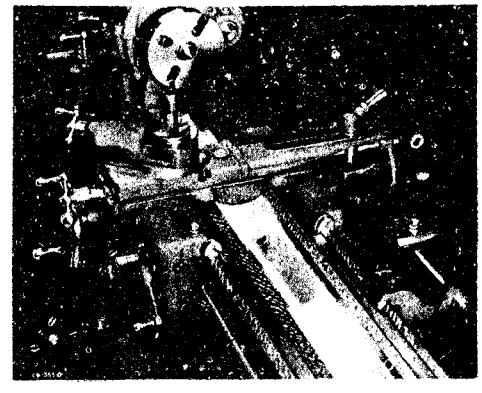

PLATE 35. Close-up of lathe carriage and headstock showing how the units are aligned on the lathe bed by inverted V-ways which are hand scraped straight and parallel. Note taper attachment at right side of illustration. (Courtesy - South Bend Lathe Works.)

OBJECTIVES: The FINAL ALIGNMENT of the CARRIAGE WAYS to the AXIS of HEADSTOCK SPINDLE.

1. Cross slide movement to be square with axis of headstock spindle.
2. Flat ways to be level, longitudinally and transversely.
3. Carriage V-slides to be fitted to bed ways with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

To determine the variation from correct alignment, the following test is now conducted. Incidentally, any set up which will accomplish the same purpose as the one here described may be used. In the present case a four jaw chuck is attached to the headstock spindle and a steel PARALLEL is then lightly clamped in the jaws, as illustrated in Fig. 26.63. The PARALLEL is adjusted so that approximately half of its length extends on either side of the spindle axis. Position the cross slide on the carriage, insert the cross slide gib and adjust for sliding pressure. Attach the gib bracket and adjust the carriage gib for sliding pressure. Next clamp the carriage to the bed.

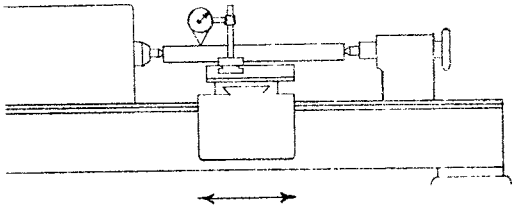

Fig. 26.62 Alignment of head and tail centers in vertical plane.

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathes
0 to .0008"	0 to .001"	0 to .0015"

(High at tailstock end)

A DIAL INDICATOR is now mounted on the cross slide and placed in contact with the PARALLEL near one end, for example, at (A) in Fig. 26.63. Revolve the spindle, meanwhile adjusting the PARALLEL by tapping it. A zero-zero reading must be registered by the DIAL as each end (A) and (B) of the PARALLEL comes in contact with the plunger button of the instrument. When this is accomplished, the PARALLEL is square with the axis of the spindle.

Now turn the spindle until the steel PARALLEL is approximately level. Maintained in this position, the button of the device will not ride off as the slide rest is moved in and out transversely.

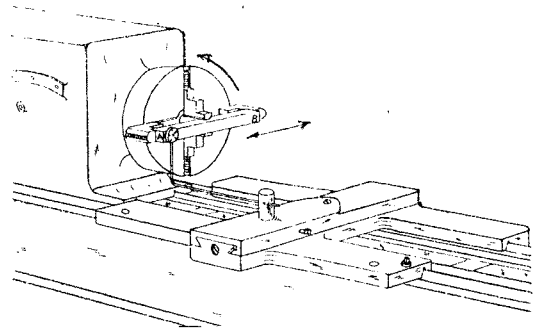

Fig. 26.63 Showing method of adjusting PARALLEL square to axis of spindle. Revolve spindle and adjust PARALLEL until a zero-zero reading is obtained as each end of the PARALLEL makes contact with DIAL INDICATOR.

Since a unilateral tolerance is allowed, as shown in Fig. 26.64, the DIAL can have a minus reading only, when moving the cross slide from the front side of the lathe towards the center. Conversely, it can have a plus reading only, when moving away from the center, towards the front side of lathe. If the tolerance is not exceeded, the transverse movement of the cross slide is satisfactory. However, if it does not pass this test, then the two V-slides of the carriage must be scraped so as to "throw" the cross slide in the correct direction and by the proper amount. When this test is passed, OBJECTIVE NO. 1 is satisfied.

By occasionally laying a PRECISION LEVEL on the flat ways in both the longitudinal and transverse directions, as shown previously, notably Fig. 26.30 and Fig. 26.32, a close check can be kept on OBJECTIVE NO. 2. This is essential because there is a tendency to tilt these surfaces if the scraping performed on the carriage slides is carelessly executed.

IMPORTANT:

It might be worthwhile to emphasize that, although we are aligning the carriage ways, the correction is made on the carriage slides.

The surface quality required by OBJECTIVE NO. 3 should be produced simultaneously.

NOTE:

Any rescraping of the carriage V-slides may also necessitate reworking the rear carriage gib bracket bearing

to a correct alignment with the rear carriage gib way of the bed. Obviously, the gib piece will also be affected by this change and may require extensive rescraping depending upon the amount of error disclosed.

Sec. 26.66
OBJECTIVES: Final Alignment Test of Compound Rest Top.

1. Movement of compound rest top to be parallel to headstock spindle in vertical plane.

PROCEDURE:

The compound rest is used for machining or boring a steep taper and unless the tool is exactly on-center throughout its entire travel, a true taper will not be generated. In short, the surface lines of the work piece will be hyperbolic instead of straight and tapered. It is to insure this condition that we make a final test on the compound rest top, after the carriage V-slides have been scraped so as to correctly align the movement of the cross slide.

Returning to the procedure, the test bar is inserted into the headstock spindle and, after the customary runout is performed, revolved to place the mean position of eccentricity error in the vertical plane. A DIAL INDICATOR mounted on the compound rest top should be adjusted to permit the INDICATOR button to touch the test bar at the vertical diameter.

The compound rest is swiveled so that the movement of the compound rest top parallels the bed ways. By turning the feed screw, the compound rest traverses, sliding the button along the test bar.

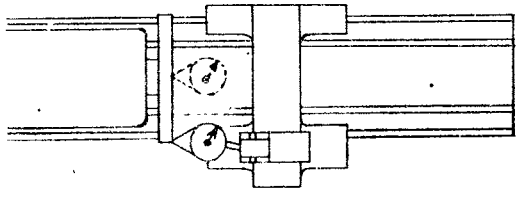

Fig. 26.64 Testing alignment of cross slide movement to axis of headstock.

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathes
0 to .0005"	0 to .001"	0 to .001"

(To face hollow or concave only on 12" diameter)

The tolerance allowed is shown in Fig. 26.65. If this is exceeded, one possibility could be that the flat ways of the compound rest swivel were not scraped parallel with the swivel slide. Sec. 26.20 discusses a method of dealing with this.

This completes all scraping operations on the lathe. The feed screws of the cross slide and compound rest may now be checked.

Sec. 26.67
Back Lash on Feed Screws

PROCEDURE:

The accompanying chart Fig. 26.66, discloses the recommended standards for the back lash on the cross feed screw and on the compound rest feed screw.

The feed screws are tested for back lash, while threaded into their respective nuts.

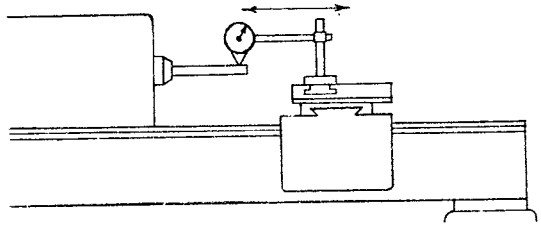

Fig. 26.65 Final alignment of compound rest top. Movement of slide parallel with work spindle in vertical plane. Tol. max. .0035" per foot.

If the tolerance is exceeded, the nut should be replaced or, if of the compensating kind, adjusted to take up for wear.

Now that the alignments of the lathe members are finished, the next operation is the assembly of miscellaneous unattached parts. Strictly speaking, this is not scraping work, but it may nonetheless be the responsibility of the operator.

Sec. 26.68
Assembly of Lead Screw and Apron

In assembling the lead screw and apron, one point to watch is the adjustment that may be required between the lead screw bearings and the half nut to accomodate them to each other under the new and changed conditions. Since more or less metal has been scraped from both the bed ways and the carriage slides, it is obvious that the present position of the half nuts

will be lower in relation to the lead screw than formerly. Likewise the rack may have to be lowered to prevent excessive play in the handwheel. Adjustments of this nature, though essential, do not pertain to the subject matter of this book and therefore will not be discussed further. However, the importance of the Lead Screw in the efficient operation of the machine justifies the space allotted to several tests concerning its alignment to the halfnut and the bed ways. These matters will now be discussed.

Sec. 26.69
Lead Screw Alignment.

PROCEDURE:

Due to the removal of metal from various bearing surfaces, the lead screw will be misaligned if replaced without adjustment of its bearings. For proper adjustment the lead screw must be lowered to obtain a correct alignment with the half nuts. In addition, the lead screw must be aligned to the bed ways.

To test this alignment the lead screw is inserted in the bearings. The carriage is placed at the mid-point on the bed ways, closing the half nuts on the lead screw. A simple indicating jig, or the one shown in Fig. 26.67a, is then made up. When set in place it is guided by the front inverted V-way of the bed, and supported at the other end by the rear inverted V-way.

Next a DIAL INDICATOR is attached to the jig with the button adjusted to touch the lead screw at the vertical diameter. The apparatus is moved along the ways and checks are made at short intervals from end to end of the lead screw. This is repeated with the button at the horizontal diameter. The tolerance allowed is shown in Fig. 26.67b. If exceeded, the lead screw bearings are replaced or shimmed to obtain the correct alignment.

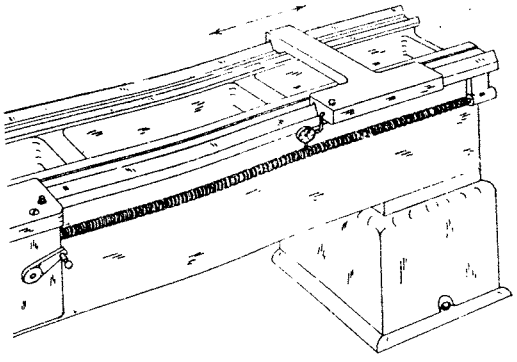

Fig. 26.67(a) General arrangement for testing lead screw alignment with bed ways.

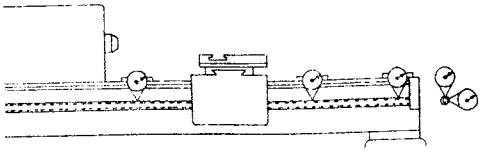

Fig. 26.67(b) Alignment of lead screw

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathes
0 to .004"	0 to .004"	0 to .006"
(Parallel with ways horizontal and vertical)		
0 to .006"	0 to .006"	0 to .008"
(Alignment of half nut horizontal or vertical)		

Sec. 26.70
Lead Screw Cam Action

PROCEDURE:

This test is designed to show the maximum permissible cam action of the lead screw. Fig. 26.68 shows the set up which should be self explanatory. The tolerance is also indicated.

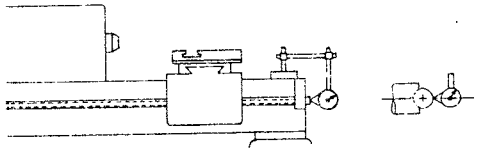

Fig. 26.68 Lead Screw Cam Action

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathe	20" to 36" inc. Engine Lathe
max. .0003"	max. .0004"	max. .0005"

Fig. 26.66 (a) Back Lash on Cross Feed Screw
(b) Back Lash on Compound Rest Screw

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathes
(a) .004"	.004"	.005"
(b) .004"	.004"	.005"

Sec. 26.71
The Accuracy of Lead Screws

The accuracy of lead screws should meet the recommended standards shown in the accompanying chart Fig. 26.69. In

Fig. 26.69 Accuracy of lead screw

RECOMMENDED STANDARDS

Tool Room Lathe	12" to 18" inc. Engine Lathe	20" to 36" inc. Engine Lathe
(±) .001" (lead per foot)	(±) .0015"	(±) .002"
(±) .0004" (lead in any 4")	(±) .0005"	(±) .0007"

reality, this is a manufacturer's test and most shops would not be concerned with this phase. Several methods of testing the pitch error in lead screws will be provided, though, for the benefit of those interested.

One application utilizes center point combinations. In this operation PRECISION GAGE BLOCKS, mounted in a holder, provide an accurate method for checking the pitch of the lead screw threads.

Another method employs optical instruments for comparative testing of the lead screw against a precision test bar.

A third procedure uses the travel of the carriage to test the pitch error. This method will be discussed at some length because it can be performed with equipment readily available in the average shop.

Sec. 26.72
Pitch Error in Lead Screws

(The accuracy tests of lead screws is based on a reference length of 12" with a further subdivision of 1/3 or 4".)

PROCEDURE:

This procedure involves taking the measurements over a distance of 12". Starting at any distance from the headstock, the half nut is closed on the lead screw. Then the carriage is moved along the bed by turning the lathe spindle by hand. A count is made of the total number of revolutions which theoretically should advance the carriage the standard 12".

Two measurements are executed. The first, is made in conjunction with a fixed type end gage, as shown in Fig. 26.70a. This determines the starting position.

The second measurement is performed without the fixed type end gage, as shown in Fig. 26.70b. This is the stop position.

Since the figures are nearly self-explanatory we shall call attention here to only a few salient features. The set up is arranged as follows:

A ground stud (1) is bolted to the face plate. A sleeve (2) having a close sliding fit is slipped over the stud. Next a bar (3) is clamped to the top of the lathe bed. To the bar is fastened a DIAL INDICATOR (4). The DIAL button should be placed in contact with the sleeve. Some discretion is required when choosing the contact position, so that when the sleeve is removed, the stud will clear the DIAL INDICATOR as the lathe spindle is turned.

The lathe carriage is stationed on the bed at the point where the lead screw is to be tested. Another DIAL INDICATOR (5) is attached to the carriage. A stop (6) is clamped approximately 12" from the INDICATOR (5). A fixed type end gage (7) is made up to exactly 12" in length. It is positioned in a PRECISION V-BLOCK (8) laid on the inverted V-way.

After closing the half nuts all slack is taken up in the driving mechanism by turning the spindle until the button of the DIAL INDICATOR (5) is in contact with the fixed end gage (7). This INDICATOR reading is jotted down for later reference.

The DIAL INDICATOR (4) is now positioned against the sleeve (2) with sufficient pressure to register on the DIAL, and this reading, too, is noted. The sleeve (2), the end gage (7), and the PRECISION V-BLOCK (8) are removed. Following this, the spindle is turned the exact number of times which mathematical calculations show would traverse the carriage 12". The actual variation over or under represents the Pitch Error.

To illustrate this procedure let us assume an imaginary example:

Assuming the lead screw has eight threads per inch, the pitch of thread would then be 1/8". Therefore, the spindle must be revolved eight times to move the carriage one inch, or ninety six times to traverse the carriage the required 12". The actual travel of the carriage will

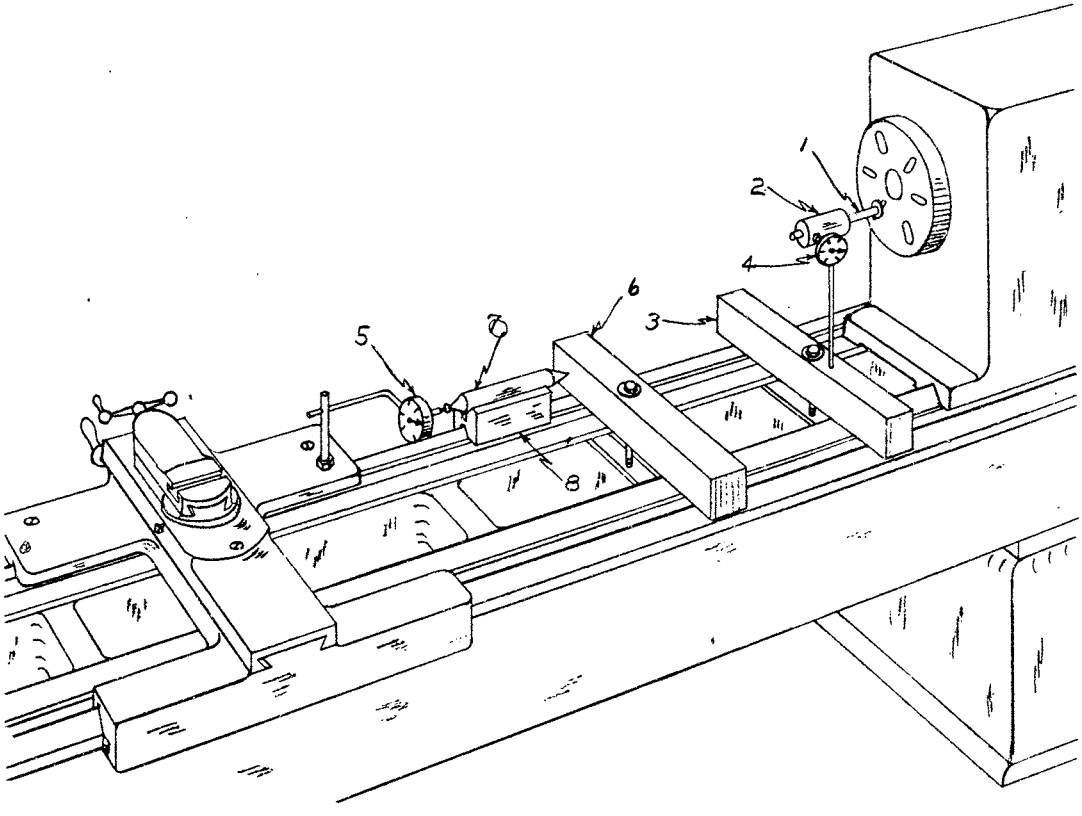

Fig. 26.70(a) Testing pitch error in Lead Screw by comparison with End Gage. 1st phase Starting Position.

(1) ground stud (2) sleeve (3) parallel bar (4) DIAL INDICATOR (5) DIAL INDICATOR (6) parallel bar (7) end gage (8) precision V-block.

be either more or less than 12" and this difference when measured will be the pitch error.

In practice, the spindle is revolved ninety five times and as the last turn begins, the sleeve is inserted on the stud. The ninety sixth revolution is completed when the reading on the INDICATOR (4) attains the same value as previously recorded. At that point further movement should be stopped.

We now turn to the INDICATOR (5). The button of this DIAL should be in contact with the stop (6). What ever the difference between the first reading which was jotted down and the present reading will constitute the pitch error of the lead screw in thousandths of an inch per foot, either plus or minus.

Sec. 26.73
Limitations Affecting the Accuracy of Static Alignment Tests.

With the lathe completely assembled it is well to try the lathe under actual operating conditions. Up to this point we have depended principally upon a DIAL INDICATOR to inform us as to the accuracy of our alignments. Furthermore, no working pressure has been applied to the bearing surfaces. However, we may feel reasonably certain that the machine will produce accurate work, provided the following conditions were fulfilled, namely:

1. If an accurate, sensitive DIAL INDICATOR was used.
2. If testing set-ups were made accurately.

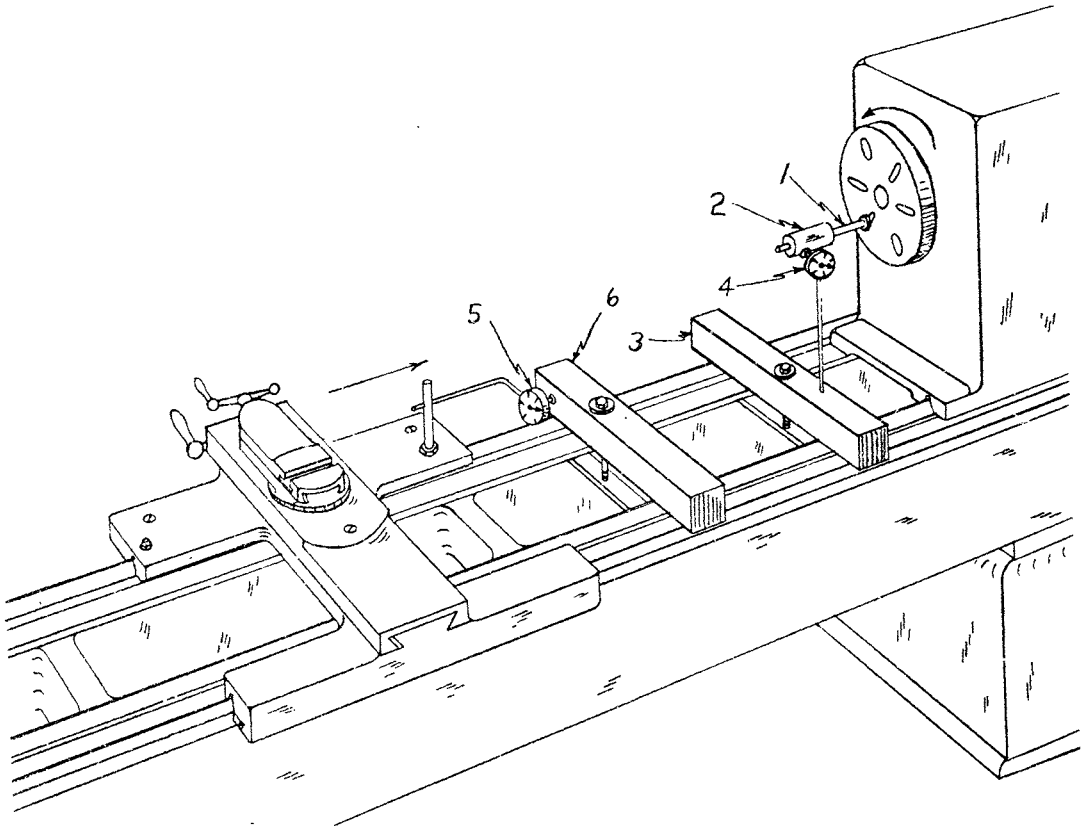

Fig. 26.70(b) Testing pitch error in lead screw. 2nd Phase. Stop Position. The carriage has been advanced 12 inches more or less in direction of Arrow. Any variation in the reading of DIAL attached to the carriage indicates the pitch error.

3. If the tests were conducted so as to obtain pertinent information. Unless clear thinking is the order, it is entirely possible to perform spurious tests which prove nothing and have no significance or application to the problem.
4. If a careful and workmanlike job of scraping was done.
5. If room temperatures did not vary widely during the period when alignment tests were made.
6. If all surfaces of members in contact were free of dirt, grit, and thick coatings of marking compound or films of heavy oil.
7. If indicating jigs were rigidly made and properly applied.
8. If SURFACE PLATES, Templates, and other spotting tools were in perfect condition.

When any of these factors has been slighted by the scraping operator, or if machine repairs on spindles, gearing etc. were performed in a slip shod fashion, then we are almost certain to experience trouble in securing satisfactory results under actual operating conditions. To dismantle the lathe again, to correct some individual fault, is definitely not good practice. Furthermore, it suggests the possibility that other dependent surfaces or alignments may also require rectification

It is always good practice to run in the machine under power for about one hour. During this warming-up period, the various members are repeatedly tested for quietness and smoothness of movement. When the machine attains a constant, normal, operating temperature the Final Tests under Working Conditions may be performed.

Tests Under Operating Conditions

Now we will proceed to tests under actual working conditions.

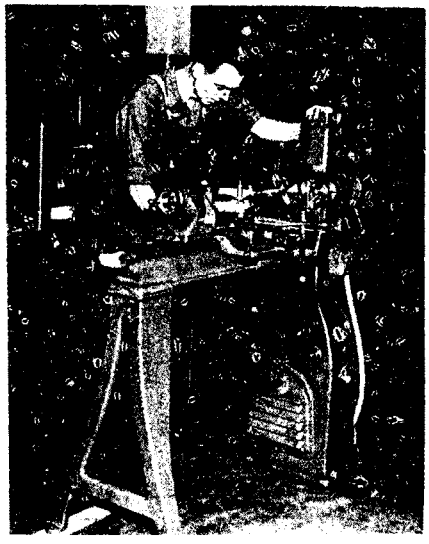

PLATE 36. Inspector taking a trial cut on a test piece held in lathe chuck to test truth of headstock. (Courtesy - South Bend Lathe Works.)

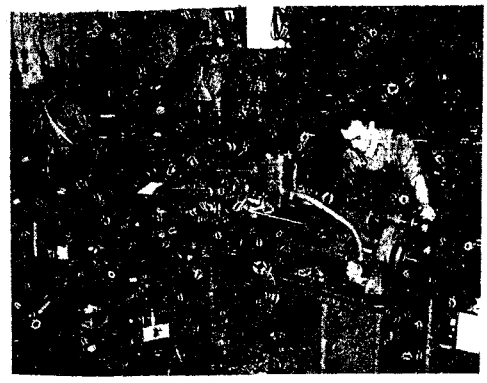

PLATE 37. General view in factory showing inspector at work testing the alignment of the headstock spindle on the lathe bed. Note the test bar in spindle of lathe to left rear. (Courtesy - South Bend Lathe Works.)

Sec. 26.74
Lathe Must Turn Round with Work Mounted in Chuck.

PROCEDURE:

A short bar of steel, two or more inches in diameter, is placed in the chuck. A skim cut is taken on the bar, following which it must check round within the tolerances given in Fig. 26.71. If excessive

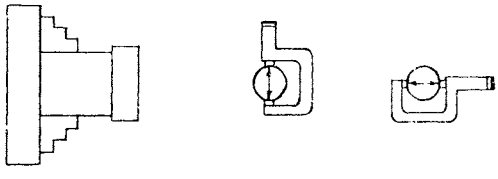

Fig. 26.71 Lathe must turn round with work mounted in chuck.

RECOMMENDED STANDARDS

Tool Room Lathe	12" to 18" inc. Engine Lathe	20" to 36" inc. Engine Lathe
.0003"	.0004"	.0008"

out-of-roundness is noted, an examination of the headstock main bearings and spindle should reveal the cause of the inaccuracy.

Sec. 26.75
Lathe must turn Cylindrical with Work Mounted in Chuck.

PROCEDURE:

A length of steel bar stock of suitable diameter is mounted in the chuck. Two collars are machined on the work piece; one collar near the chuck jaws, the other collar at the free end of the bar.

The next step is to take a very light finishing cut across one collar, and without changing the adjustment of the tool, the cut is continued across the other collar. The diameter of each collar should be the same, otherwise a taper is indicated. The tolerance allowed is shown in Fig. 26.72.

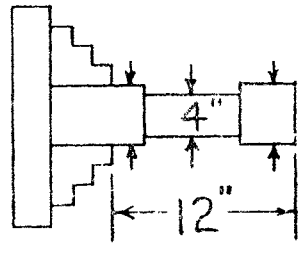

Fig. 26.72 Lathe must turn cylindrical with work mounted in chuck.

RECOMMENDED STANDARDS

Tool Room Lathe	12" to 18" inc. Engine Lathe	20" to 36" inc. Engine Lathe
.0008"	.0015"	.002"

There are several possible causes if a taper is in evidence, namely:

1. The lathe is no longer level. This is an unlikely possibility if the lathe has not been moved from the location where it was reconditioned. It is,however, a simple matter to check the levelness of the lathe to make certain that the shims have not shifted.
2. The ways have a "wind". If the outer inverted V-ways of the bed were scraped in a slipshod manner it is possible they are not straight. They must be checked to determine their accuracy. Pertinent tests would include, the Microscope & Taut Wire System, Water Level System.
3. The headstock is misaligned. This means that the headstock spindle may not be parallel to the DATUM PLANE. Repeating tests given in Sec. 26.63 and shown in Fig. 26.59 and Fig. 26.60 will determine if the error can be charged to this component. In order to correct any misalignment discovered, the entire scraping and testing procedure commencing with Sec. 26.63 must be repeated because related members were dependent upon the alignment of the headstock spindle and they will now be out of true.

(As an alternative to machining two collars, the accuracy of alignment of the headstock spindle may be determined by boring a hole with the work piece held in the chuck. If a taper develops, the source of error may be located in one of the possibilities outlined above.)

Sec. 26.76
Lathe must turn cylindrical with the Work mounted between centers.

PROCEDURE:

A length of cylindrical bar stock of appropriate diameter is centered at both ends and placed between the lathe centers. Using a light cut and fine feed, two collars of the same or random diameter are machined on the bar. One of the collars is formed near the headstock center and the other adjacent to the tailstock center. Certain measurements will now be made on these collars to prove that the lathe can turn out accurate work as specified above.

1. To determine roundness.

The collar at the headstock end, in particular, should be "miked" because there the error, if any, will be most pronounced. The collar is measured on the vertical and horizontal diameters and at intermediate points. If out-of-roundness is apparent the error may be attributed to the following sources:

(a) Inaccurate spindle or spindle bearings. Refer to Sec. 26.74.
(b) Spindle center run out. Refer to Sec. 26.59 and see Fig. 26.55.

These causes of out-of-roundness should be investigated and the fault corrected before searching for other possible errors.

2. To determine cylindricity:

Next a very light finishing cut is taken across both collars without changing the setting of the tool. Then the diameter of each collar is "miked" at several places. The tolerance allowed is shown in Fig. 26.73. The measurements of one collar

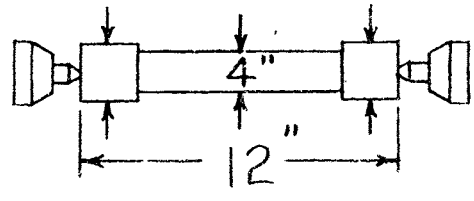

Fig. 26.73 Lathe must turn cylindrical with the work mounted between centers.

RECOMMENDED STANDARDS

Tool Room Lathe	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathe
.0004"	.0008"	.001"

must correspond to the measurements of the second, otherwise a taper is indicated. A taper may be due to the following reasons:

(a) The bed is not level. To dispose of this possibility, repeat the leveling checks described in Sec. 26.38. The tolerance is given in Fig. 26.29a and Fig. 26.29b.

(b) The axis of tailstock spindle is not in-line with axis of headstock spindle in horizontal and/or vertical planes. The following system is used to determine in which plane the error is located.

Any error caused solely by a misalignment in the horizontal plane can be eliminated by mere mechanical manipulation of the tailstock. First, "mike" the collars, and if the diameter of the collar at the tailstock end is the larger of the two, the lateral adjustment screws are turned to move the tailstock top in its transverse way towards the front of the lathe. On the other hand, if the collar at the tailstock end has a smaller diameter the tailstock is set over towards the back of the lathe. Repeated cuts, measurements, and adjustments are made until the diameters of both collars are identical. In this way all error in the horizontal plane is eliminated.

To determine if misalignment is present in the vertical plane, the following procedure may be adopted. This test is most easily performed by mounting a DIAL INDICATOR on the tool post and adjusting the button to touch one of the turned collars at the vertical diameter. The pointer is set to zero, and then without changing the setting, the carriage is traversed along the bed ways and the reading noted at the other collar. If there is no misalignment in the vertical plane, the reading will be identical. If there is a difference, correction is made by scraping the slides of either the headstock or tailstock, whichever has its axis higher as measured from the bed ways.

CAUTION:

The machining of the two narrow test collars of the same diameter, one at each end of the bar, at a single setting of the cutting tool, is not the infallible test for alignment of the axis of the tailstock spindle to axis of headstock spindle that it is popularly supposed to be. Should the tailstock spindle be either higher or lower than the headstock spindle, it is still possible to machine, without changing the setting of the tool, two narrow test collars of apparently identical diameters by simply adjusting the tailstock in its transverse way. The reason for this phenomenon is that for any particular height of the cutting edge of the tool there will be a certain set-over of the tailstock which will apparently compensate for the misalignment of the tailstock axis in the vertical plane. In reality, the collars will be hyperbolic rather than cylindrical in character. Where the misalignment in the vertical plane is small, variations in micrometer readings on the several diameters will be almost imperceptible. Therefore, in order to make an accurate test of the alignment of the head and tail centers in the vertical plane, the following procedure should be adopted.

Machine two collars at opposite ends of a bar held between centers, using a light cut and fine feed. Measure the collars with a micrometer. If the measurements are not the same, adjust the tailstock transversely, out or in as required, and machine again. Machine and measure consecutively until the collars "mike" identically. Then fasten a DIAL INDICATOR to the tool post of the carriage and adjust the button of the instrument to the vertical diameter of one collar. Traverse the carriage along the bed and observe the DIAL reading at the other collar. If the reading is zero-zero the axes of the head and tail centers are correctly aligned in the vertical plane.

An additional test may be made which is based on the premise that if the headstock spindle and tailstock spindle are correctly aligned to each other in both planes, then the height of the cutting tool above, below, or on-center will produce identical diameters in the two test collars without changing the setting of the tool on the machining cut. Thus after obtaining equal diameters on the two collars by adjusting the tailstock, a second cut is made across both collars, this time with the cutting edge of the tool raised or lowered from its first setting. Any misalignment of the tailstock in the vertical plane will be immediately apparent by a difference in diameters of the two test collars.

Sec. 26.77
Lathe to Face Concave Only

PROCEDURE:

For this test the face plate is mounted on the headstock spindle. Lock the carriage and set the lathe cutting tool to take a light faceing cut. After the cut is completed, the alignment of the guiding way of the carriage may be tested by means of the Three Papers Method. (Sec. 22.4)

To perform this operation, three paper slips are positioned in a row against the face plate. One paper is placed near the middle. The other two are oppositely located at the outer rim of the face plate. They are held there by pressing them with a hardened steel straight edge. By judging the drag of the center paper as it is removed, the operator determines if the tolerance shown in Fig. 26.64 has been exceeded. If this is the case the carriage ways are misaligned with respect to the axis of the spindle. Correction of the error calls for rescraping the carriage slides, as discussed in Sec. 26.65.

This concludes the tests made on the assembled lathe. If all tests were satisfactorily finished, the lathe, insofar as the scraping and alignment of major members are concerned, may be considered completed.

No mention has been made of minor components, such as taper attachments, special fixtures etc. But it is felt that if scraping or alignment is needed on these members, there is sufficient information available in these pages to assist the scraping operator when treating them.

Accepted standards of Accuracy for a few common attachments are included herewith to serve as a guide.

Sec. 26.78
Chuck Run Out

PROCEDURE:

The recommended standards of accuracy for chucks are illustrated in the accompanying Fig. 26.74.

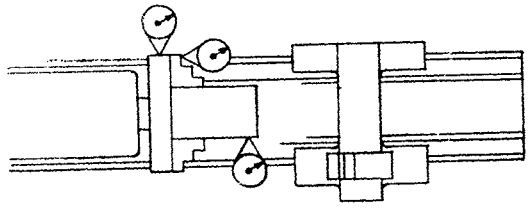

Fig. 26.74 Chuck run out.

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathes
.003" (face and periphery)	.003"	.004"
.003" (face of steps)	.003"	.004"
.003" (Bar test 3" from end of jaw. Bar diameter same as hole)	.003"	.004"

Sec. 26.79
Collet Chuck Run Out

PROCEDURE:

The set up shown in Fig. 26.75 will indicate any variation from the recommended standards for collet chucks.

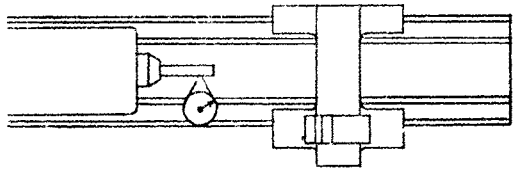

Fig. 26.75 Collet chuck run out.

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathe
0 to .001" (one inch from spindle)	0 to .001"	0 to .001"

Sec. 26.80
Face Plate Run Out

PROCEDURE:

The accompanying Fig. 26.76 furnishes the accuracy standard for face plates.

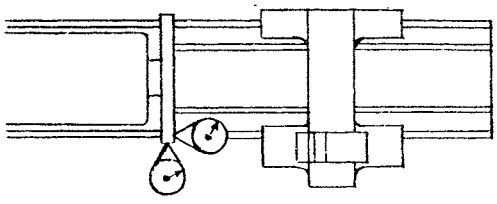

Fig. 26.76 Face Plate run out.

RECOMMENDED STANDARDS

Tool Room Lathes	12" to 18" inc. Engine Lathes	20" to 36" inc. Engine Lathe
0 to .0005" (on diameter)	0 to .001"	0 to .0015"
0 to .001" (on face at nominal diameter)	0 to .0015"	0 to .002"

Sec. 26.81
Effects of Inaccurate Leveling

Although the lathe was leveled prior to scraping, this procedure must be repeated again if the machine is moved to another place for permanent erection. Any relocation of the bed necessitates the exercise of due care on the part of the user. If the machine is placed in operation when the lathe bed is not level, serious trouble will be experienced. The ways of the bed become twisted thereby initiating a whole series of unfortunate consequences. For example, when the ways of the bed are twisted due to faulty leveling the carriage slides cannot fit properly. Operated in this condition, chatter marks will be generated on the work piece.

A "wind" in the bed ways, attributable to improper leveling, will also twist the headstock out of line. This binds the spindle in its bearings. The bearings may score and deterioration is accelerated. Chatter marks are formed on the work piece by this cause also.

Improper leveling, besides impairing surface quality, likewise affects the accuracy of the work output in the following manner. Work held in a chuck cannot be turned straight, nor can a hole be bored which will not taper. It is also impossible to turn work straight when held between centers.

To function accurately, a lathe regardless of size, or weight must be perfectly level before being placed in use. It is the purpose of the leveling process to relieve strains and distortion and restore the bed to the plane in which it was scraped.

Chapter 27

THE HORIZONTAL MILLING MACHINE

The horizontal milling machine, shown in **Fig. 27.1**, is widely used not only for job work in machine shops, but also for mass production output in factories.

The machine to be described is of elementary design. All major components of standard machines have been incorporated and various types of bearing surfaces assigned to provide the maximum number of points of interest to the scraping operator. In this undertaking, major emphasis has been laid on the problem of scraping and aligning the sliding bearings. The mechanical side has, in so far as possible, been subordinated. If the operator understands the underlying principles, and is able to duplicate the work described here, he will have little trouble with horizontal millers of comparable design.

Readers should not misconstrue the meaning of the term "elementary." As

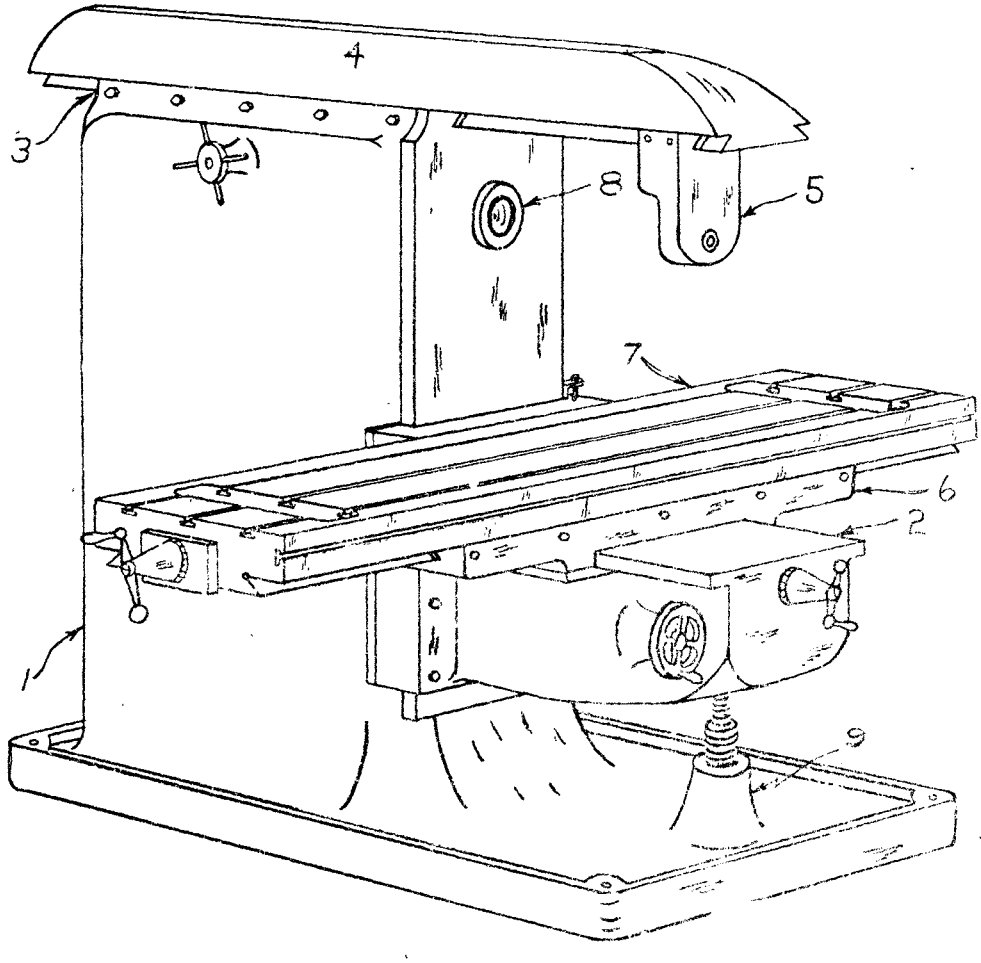

Fig. 27.1 View of Horizontal Milling Machine

(1) column (2) knee (3) over arm support (4) over arm member
(5) outer bearing arbor support (6) saddle (7) table (8) spindle
(9) pedestal boss

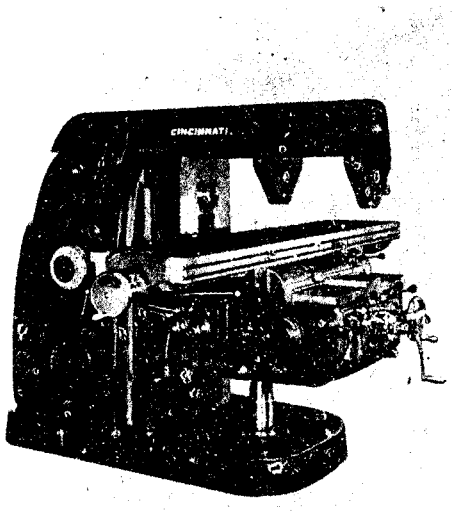

PLATE 38. Completely assembled horizontal milling machine. Notice that face of column is divided and that column ways are the square edge type. (Courtesy - The Cincinnati Milling Machine Co.)

used, it signifies a practical, functioning machine in every sense of the word.

Sec. 27.1
Components

The members of a horizontal milling machine of special concern to the scraping operator are listed below in the sequence they will be dealt with. This is not an inflexible order as the concluding NOTE: explains.

1. The Column: The frame of the horizontal milling machine is a large casting and is the foundation upon which all other members are mounted. Since the frame supports the weight of all the members, in addition to the work piece, it necessarily must be very strong and rigid. Strictly speaking, only the vertical portion of the frame is called the column. The lower horizontal part is more often referred to as the base.
2. The Knee: The function of the knee member is to uphold the saddle, table, and the weight of the work piece and also to withstand the pressure of the cut. It is vertically guided by the column ways and is adjustable as to height.
3. The Over Arm Support: This is not a separate member but comprises bearing surfaces of a dovetail construction occupying a horizontal position on top of the column. It supports and guides the over arm member.
4. The Over Arm Member: This is a massive casting adjustable along its axis and used to carry the outer bearing arbor support.
5. The Outer Bearing Arbor Support: This member, which is adjustable along the over arm, provides a support for the free end of the arbor.
6. The Saddle: This member which supports the table is divided into two general classifications.
   a. The Plain Saddle which is transversely adjustable on the knee and is guided by the knee ways.
   b. The Universal Saddle, which is sectional, has a transverse movement on the knee and additionally has an angular movement in the horizontal plane.
7. The Table: The work piece, and also various attachments, such as the dividing head, vise etc., are clamped to the table for which purpose "T" slots are provided. The table moves longitudinally, guided by the ways of the saddle.

NOTE:

Some mechanics prefer to take up these members in a somewhat different order. An alternative sequence would be as follows: column, knee, saddle, table, over arm support, over arm member, and outer bearing arbor support.

Sec. 27.2
Selecting the Datum Point

Before initiating the scraping work, we must first decide upon a Datum Point which in this particular case is readily determined. It will be the axis of the spindle. We choose this member for three reasons, viz:

1. The spindle is the component part whose position would be most difficult to shift or modify to align with some other member or surface.
2. It is available in a convenient location.

3. It is a machine part whose accuracy, once established, will be constant.

For these reasons, the Datum Point selected for the horizontal milling machine is the axis of the spindle.

Sec. 27.3
Testing the Accuracy of the Datum Point (spindle axis).

Since the horizontal milling machine is built around, and aligned to, the Datum Point which is the axis of the spindle, it is essential that the truth of this part be above question. Otherwise, the effort expended in scraping the flat bearing surfaces may be largely wasted. Therefore, prior to dismantling the machine, three tests are made on the spindle and spindle bearings to prove their accuracy. These tests pertain to the following:

1. The spindle run out. This determines two possible conditions of the tapered spindle hole.
   a. The inclination of the axis of the tapered hole to the axis of rotation of the spindle.
   b. The concentricity of the axis of the tapered hole with respect to the axis of rotation of the spindle.
2. The spindle end face run out. This tests the spindle for cam action.
3. The spindle end periphery run out. The spindle end periphery run out tests for concentricity of the spindle with respect to the axis of revolution.

Sec. 27.4
Spindle Run Out Test

The test for spindle run out, illustrated in Fig. 27.2, is conducted as follows:

A precision test bar made up to fit the tapered hole in the spindle is inserted. Then a DIAL INDICATOR mounted on a Surface Gage is positioned on the table top. The button is placed in contact with the test bar at a point about 1" from the spindle. A reading is taken as the spindle is revolved slowly. After relocating the gage, another reading is taken at the free end of the test bar.

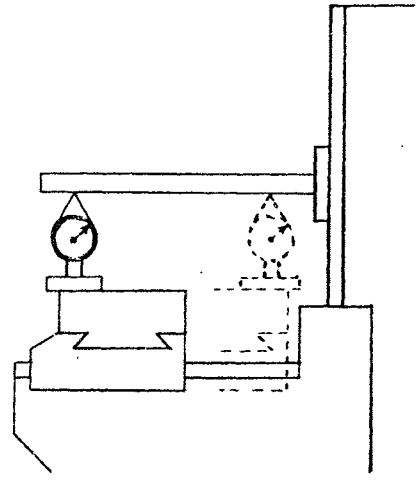

Fig. 27.2 Spindle run out. Tolerance max. .0005" at $1\frac{1}{4}$" from spindle. .001" at 18" from spindle.

If the tolerance indicated in Fig. 27.2 is exceeded at either position, there are several likely causes. In the first place, the test bar may not be seated accurately in the hole. Since this may be due to burrs or dirt, the test bar should be removed and the tapered hole in the spindle examined.

A good method of determining proper seating is to apply a thin streak of bluing to the test bar along the length of the taper. The bar is then wrung in the tapered spindle hole, removed, and both the hole and bar are examined for non-uniformity in the marking film. If neither burrs nor dirt are found, it suggests that the axis of the tapered hole in the spindle may no longer be aligned with the axis of rotation of the spindle. It is probable, therefore, that the spindle is bent. To prove this, the spindle should be withdrawn and tested between centers for concentricity. (Refer to Sec. 15.11) Any repairs to the spindle will include regrinding the tapered hole until the run out of the precision test bar is within the acceptable tolerance.

Sec. 27.5
Tests for Spindle End Face run out and Spindle End periphery run out

These tests are illustrated in Fig. 27.3a and Fig. 27.3b, respectively. It makes for convenience to conduct them consecutively, as follows:

In the first phase, a DIAL INDICATOR

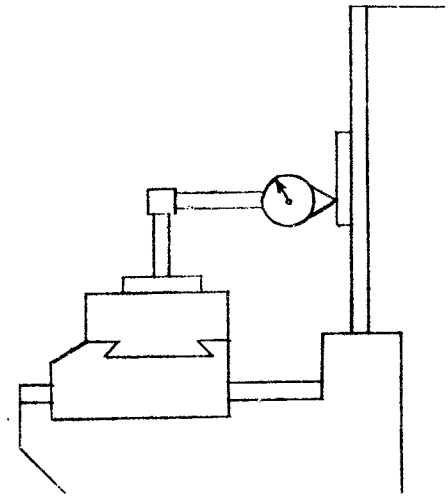

Fig. 27.3(a) Spindle end face run out. Tolerance max. .0002"

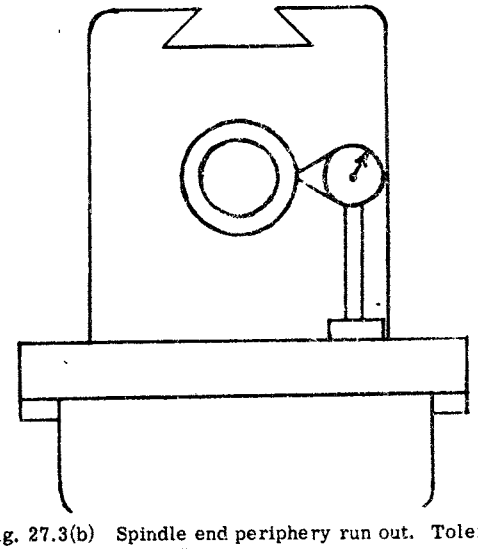

Fig. 27.3(b) Spindle end periphery run out. Tolerance max. .0002".

attached to a Surface Gage is set on the table top with the button placed in contact with the spindle face. For the second phase, the instrument is located on the periphery. In either case the spindle is turned at slow speed and the pointer of the DIAL is watched for movement.

If the face run out exceeds the tolerance shown, the source of the defect may be in the ball or roller bearings of the spindle which might be worn. These should be replaced. Another possible fault could lie in a locating shoulder which might not be in a plane perpendicular to the axis of rotation.

Next we test for periphery run out. If on this procedure the tolerance shown is exceeded, a bent spindle is a probable cause.

When all three tests can be performed without exceeding the tolerances, the spindle is acceptable for use as the Datum Point. There is now assurance that subsequent alignment tests of the bearing surfaces will be accurate if properly conducted.

Sec. 27.6
The Dummy Spindle (test bar)

On most, if not all, models of horizontal milling machines, the spindle projects beyond the column face, putting it in the way of any spotting tool applied to this surface. Since the axis of the spindle is the Datum Point for the machine, it cannot very well be dispensed with. To get around this dilemma, a dummy spindle designed for quick and easy removal is made up to take the place of the regular milling machine spindle.

The dummy spindle must be designed to duplicate the spindle it replaces. As Fig. 27.4 shows, a device having several diameters is required in order to fit the spindle bearings. The device is machined and after hardening is ground to a light press fit so that it may be pushed into and removed from the spindle bearings by hand. Side play is not permissible and should be investigated as described in Sec. 22.5. (The Shake Test)

Making the dummy spindle is not absolutely essential but it is recommended. If it is not made, considerable difficulty will be experienced in performing accurate spotting and scraping operations around the perimeter of the spindle. One alternative measure is to make up a spotting template having a central hole just large enough to accommodate the projecting spindle. It is possible, of course, to use a STRAIGHT EDGE and a SURFACE PLATE and work around the spindle but the difficulties and possibilities of error naturally are multiplied.

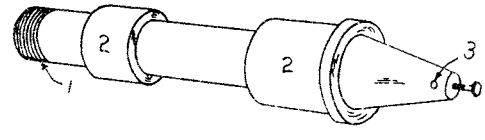

Fig. 27.4 Illustrating (dummy spindle) test bar.

(1) threads for take up to minimize end play
(2) diameters to fit spindle bearings (3) hole for DIAL INDICATOR rod.

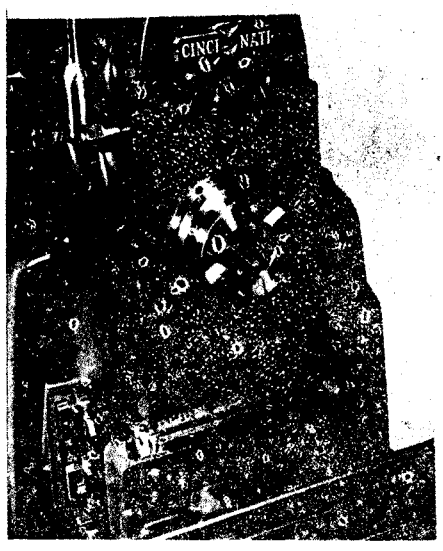

PLATE 39. Close-up of column face of horizontal milling machine showing fine hand-scraped pattern. Observe taper gib piece of knee near bottom of illustration to left of center. (Courtesy - Cincinnati Milling Machine Co.)

Sec. 27.7
Dismantling and Exploratory Examination

After verifying the accuracy of the spindle and the spindle bearings and providing a dummy spindle, the machine is

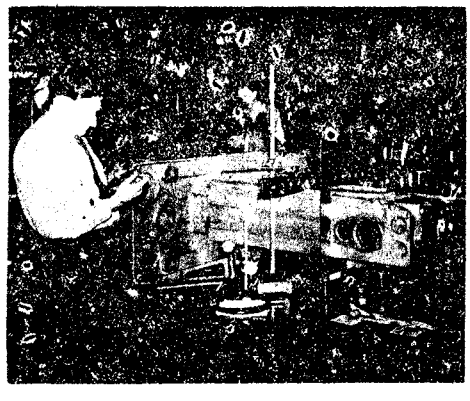

PLATE 40. Checking squareness of column face of horizontal milling machine after planing. Observe the variety of testing apparatus. (Courtesy - Kearney & Trecker Corp.)

completely dismantled. Defective gears, feed screws, bearings, etc. are transferred to the machine department for repair. It is usually the responsibility of the scraping operator, or the maintenance man in charge of rebuilding the machine, to decide if these parts are to be duplicated to their original specifications, or are to be modified to meet the changed conditions resulting from the scraping operations.

This decision will be influenced by the results of the Exploratory Examination which is made on each member, except the column. Although the need for an Exploratory Examination on the column has been eliminated by our series of tests verifying the truth of the spindle, or Datum Point, the survey should be made on other members of the machine.

The condition of the flat bearing surfaces determines what is to be done to the gearing, shafts, etc.; not vice versa. The small parts can be shifted from their original alignment much more easily than the flat bearing surfaces which are relatively inflexible.

A general survey can be made of the bearing surfaces while the components are being torn down and cleaned. As a result of this study, it is often possible to send members having excessively worn bearing surfaces to the machine shop to be milled or planed. This course reduces the amount of hand scraping but, obviously, the scraper must give proper instructions to avoid worsening the existing misalignment.

Frequently, where excessively worn bearing surfaces are encountered, the hand sanding disc grinder, or the power scraper, if available, is utilized in preference to a machining operation. In fact, many shops prefer this procedure. By using the hand manipulated tools the operator is in a position to make tests on the work whenever he sees fit and is able personally to supervise the removal of metal as he thinks advisable. This is an advantage over milling and planing because once the work piece is clamped to a machine tool and the cut started, the piece must usually be finished as set up.

Sec. 27.8
The Column

In the type of horizontal milling machine illustrated in Fig. 27.5, the column has four separate and distinct bearing surfaces. They are enumerated below in

the proper order in which the operator should work on them.

1. The face
2. The guiding way
3. The gib way
4. The gib bracket ways.

NOTE:

In addition to the several surfaces just outlined, the column also has a constructional feature known as the "Overarm Support." It is horizontally positioned at the top of the column as seen in Fig. 27.5. Under normal procedure these surfaces are not scraped in the present sequence and therefore will be discussed separately in a later section.

Sec. 27.9
Preparing to Scrape

The first step in treating the column is to remove the spindle and tip the casting over on its back. Because of the wide base, it is necessary to shore the top of the column with wood blocks so that the

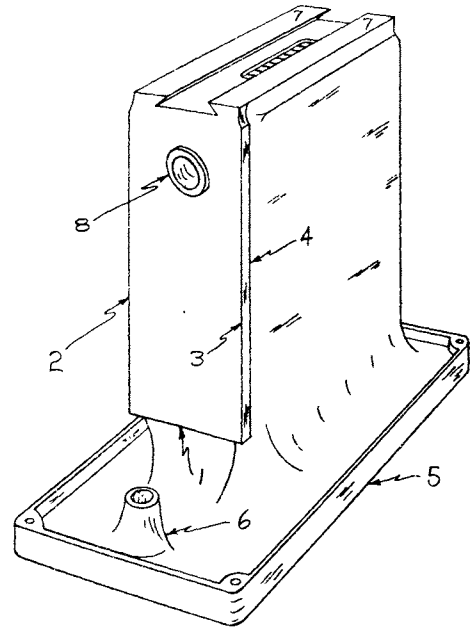

Fig. 27.5 Front and top view of main casting or column of horizontal milling machine.

(1) face (2) guiding way (3) gib way (4) gib bracket way (5) base (6) elevating screw boss (7) over arm support ways (8) spindle

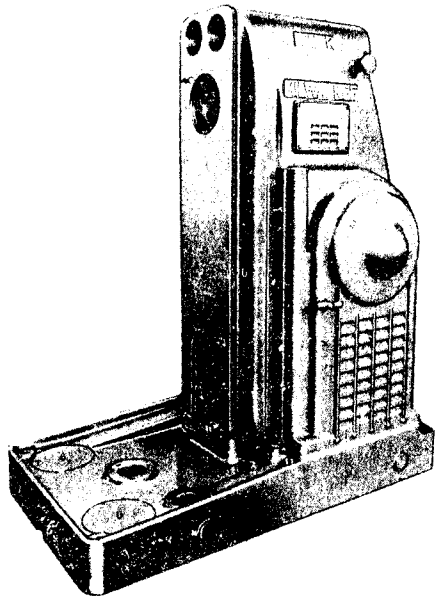

PLATE 41. Column unit of horizontal milling machine. (Courtesy - Kearney & Trecker Corp.)

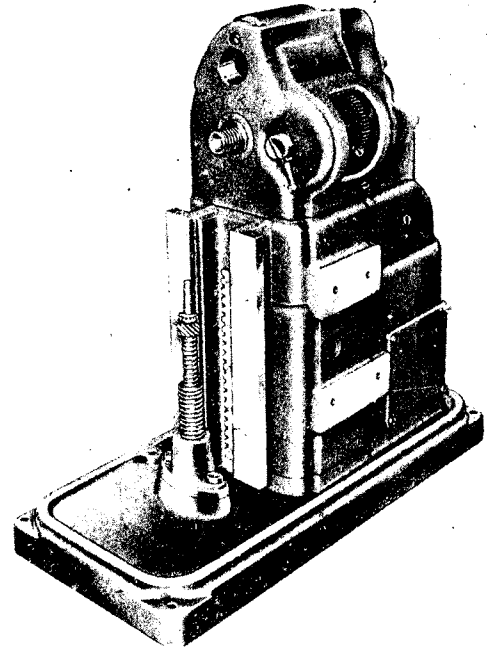

PLATE 42. Showing column casting of bench type horizontal milling machine. (Courtesy - Atlas Press Company)

work surface is approximately level. (See Fig. 27.6) The operator will discover that this position facilitates the spotting and scraping work. It will also be found very convenient during alignment tests when fitting the knee to the column.

Since this type of machine is sturdily built, and the column in particular is strongly braced, no harm results from tipping it horizontal. By this we mean that the column will not flex or warp appreciably when so placed. Furthermore, when set upright again, the scrape-finished ways will not be distorted nullifying the effort expended on them.

As the scraping proceeds it will be necessary to readjust the column from time to time, to accommodate it to various surfaces being scraped. Wood blocks of different thicknesses are useful for adjusting the column as it is turned from one side to the other. The operator should

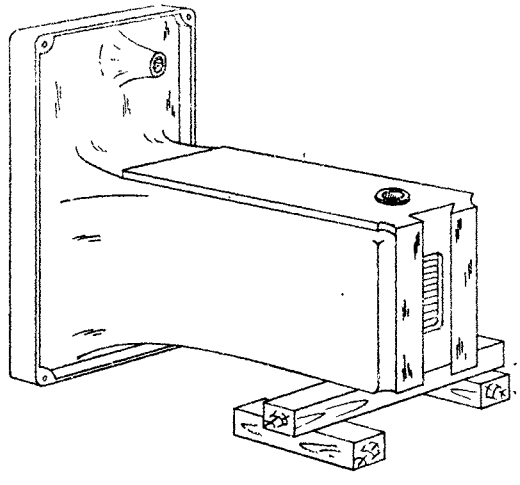

Fig. 27.6 Column adjusted to proper scraping position.

strive to keep the surface being scraped approximately level with the floor. All the checks, tests, and scraping procedures on the column described in the following pages are executed with the individual surface in the most favorable position i.e. uppermost.

We come now to the actual procedure to be followed, the scraping technique to be used, and the alignment tests which must be executed to restore the surfaces to their original accuracy and finish.

The machine under consideration will be discussed as though it were a tool room machine and thus in need of a more accurate alignment, a better finish, and truer surfaces than would be required by the average production machine. Allowances will therefore be made by the reader as he applys these instructions to his particular problem. In cases where high precision is not required, some of these steps will not be needed. Tolerances can also be liberalized on less critical alignments.

Sec. 27.10
OBJECTIVES: The Face of the Column

1. Face of column to be square with axis of spindle.
2. To be flat and have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

In examining the main casting, or column, of a horizontal miller to see how badly it is worn, the greatest wear, in the vast majority of cases, will be found at or below the mid-point of the column face. This is where the knee is most often positioned. It is also the area most exposed to chips and dirt which inevitably work their way underneath the sliding member and cause wear, felt and metal wipers notwithstanding.

The SURFACE PLATE and STRAIGHT EDGE are used alternately to spot the column face. To detect the presence of convexity in this surface the "X" test should be applied at frequent intervals.

It is essential to keep a constant check on the progress of the scraping, in order to obtain the correct alignment as speedily as possible, and to avoid over-scraping the surface. Therefore, the dummy spindle is inserted, periodically, in the spindle bearings and a DIAL INDICATOR is attached to it. By turning the dummy spindle, a swing round test is conducted as illustrated in Fig. 27.7a and Fig. 27.8a. The purpose of the test is to

prove that the column face is square with the spindle. A zero-zero reading on the

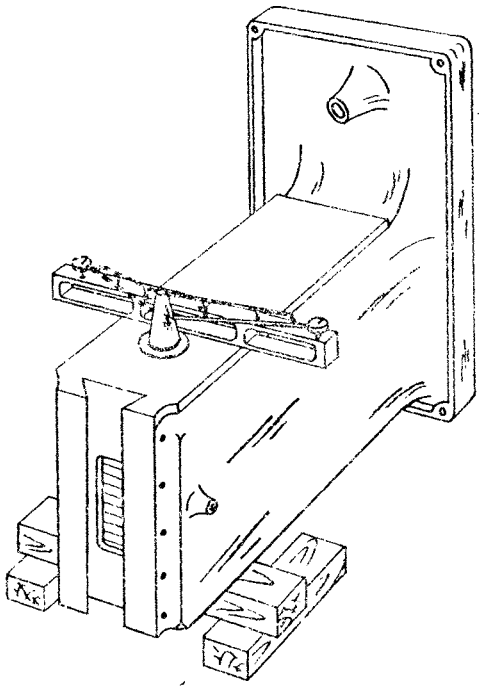

Fig. 27.7(a) Checking alignment of face of column with axis of spindle - transverse direction.

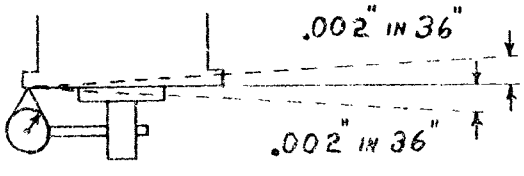

Fig. 27.7(b) Axis of spindle square with face of column. (cross-wise)

DIAL INDICATOR recorded at positions 180° apart on the test surface indicates that OBJECTIVE NO. 1 has been attained. Tolerances are shown in Fig. 27.7b and Fig. 27.8b.

It is often advisable to increase the measurable width of the column face and thereby enhance the accuracy of the test. To accomplish this a scraped PARALLEL is laid on the column as shown. Incidentally, when OBJECTIVE NO. 1 is achieved, the column face is parallel to the plane of the original factory surface.

Both OBJECTIVES are completed simultaneously.

Sec. 27.11
OBJECTIVES: The Guiding Way of the Column

1. To be square with the column face.
2. To be parallel to the plane of the original factory surface.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The first step is to turn the column on its side with the guiding way uppermost, as shown in Fig. 27.9.

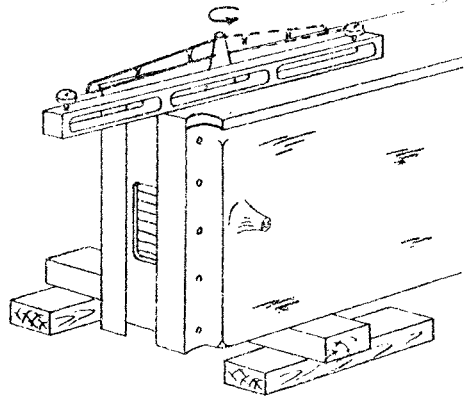

Fig. 27.8(a) Checking alignment of face of column with axis of spindle-longitudinal direction.

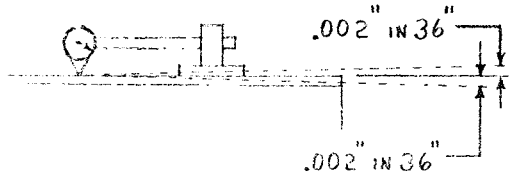

Fig. 27.8(b) Axis of spindle square with face-lengthwise.

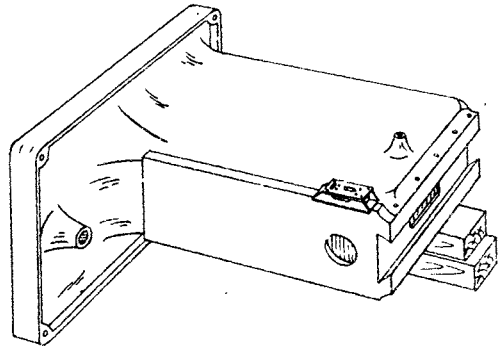

Fig. 27.9 Leveling guiding way of column preparatory to the scraping operation.

The problem now posed is how to re-scrape this particular surface parallel to the original factory plane. Every effort must be made to accomplish this with precision. One reason for this urgency is to prevent, or at least minimize, the tendency of the knee elevating screw to bind in the nut after assembly. This danger will be proportional to the amount of divergence of the surface from the original factory plane. Refer to Sec. 23.20.

Since neither the spindle nor the face of the column provides any help in locating the plane, reliance necessarily is intrusted to the PRECISION LEVEL. The proper location for this instrument is on that portion of the guiding way, closest to the top of the column. Fig. 27.9 shows the LEVEL in this preferred position. In this area the least amount of wear will have occurred. After leveling the surface, the member is blocked securely so it will not shift during the ensuing scraping operations.

Briefly the work consists of so scraping the surface that when completed, the PRECISION LEVEL can be laid on it and still indicate levelness. Achieving this condition proves that the new surface is now parallel to the plane of the original surface. Refer to Sec. 23.21 and Sec. 14.11.

Leveling the guiding way has been in the longitudinal direction, only. There is no necessity to level transversely, because a RIGHT ANGLE TEMPLATE, if correctly used will automatically hold the surface square with the column face.

The TEMPLATE just mentioned and a STRAIGHT EDGE are the proper tools for spotting this surface. All three OBJECTIVES should be attained simultaneously to complete the guiding way.

Sec. 27.12
OBJECTIVES: The Gib Way of the Column

1. To be square with the column face.
2. To be parallel with the guiding way.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The column is again turned so that the gib way is in an approximately horizontal position, facing up, as shown in Fig. 27.10a. Precise leveling of this surface is unnecessary.

To hold the gib way square with the column face, as specified by OBJECTIVE No. 1, a RIGHT ANGLE TEMPLATE is employed. A STRAIGHT EDGE is appropriate to maintain surface flatness. Alternate spotting with this combination of tools helps to create the surface bearing quality required by OBJECTIVE NO. 3.

As the scraping proceeds, check the surface occasionally for parallelism. A suitable test apparatus is the DIAL INDICATOR and attached jig. If the tolerance shown in Fig. 27.10b is not exceeded, OBJECTIVE NO. 2 is satisfied.

Work on all three OBJECTIVES is finished at the same time.

Sec. 27.13
OBJECTIVES: The Gib Bracket Ways of the Column

1. To be parallel to the column face.

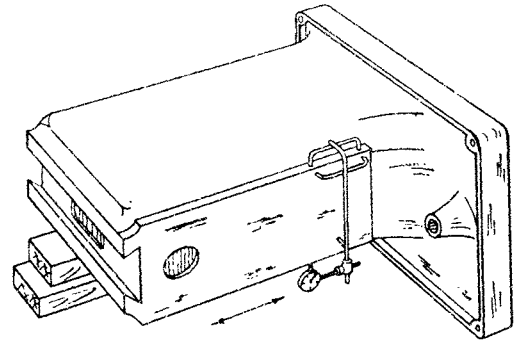

Fig. 27.10(a) Method of testing parallelism of gib way to guiding way of column with indicating jig and DIAL INDICATOR.

2. Distance between the column face and both gib bracket ways to be identical.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The gib bracket ways are most easily treated by turning the column so that they are uppermost and approximately level, as shown in Fig. 27.11a.

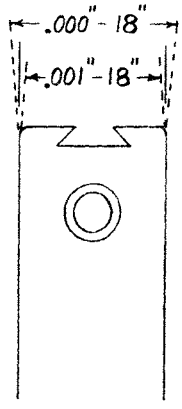

Fig. 27.10(b) Tolerance allowed for the alignment of ways of column.

To help produce a good bearing and maintain flatness, a STRAIGHT EDGE is ideal for spotting these long, narrow surfaces. If there is insufficient room, an ANGLE STRAIGHT EDGE must be used instead. A RIGHT ANGLE TEMPLATE will be helpful in holding the gib bracket ways square with the guiding way and gib

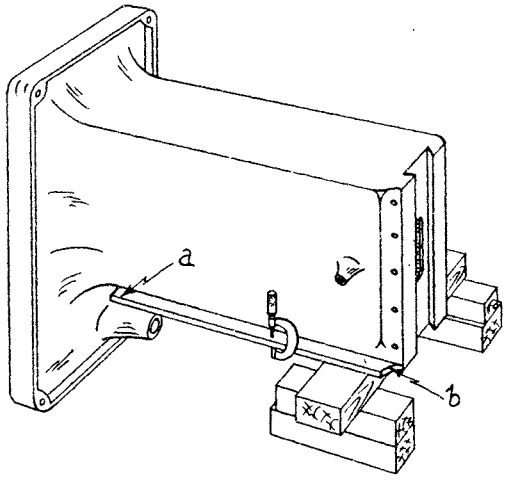

Fig. 27.11(a) Column adjusted so that gib bracket ways are in convenient working position.

way throughout their full length. Alternating these tools facilitates the job of aligning the surface.

From time to time measurements are made with a micrometer between points (a) and (b). This serves to check the parallelism in the longitudinal direction. The permissible tolerance allowed in this direction is shown in Fig. 27.11b.

It is also necessary to check transversely to satisfy OBJECTIVE NO. 1. Accurate measurements are very difficult to obtain because the width of the gib bracket ways is usually small, seldom exceeding a few inches. Nonetheless, due to the importance of this transverse check for parallelism, it is advisable to devise a means of increasing the accuracy of the tests.

One good method is to clamp a long PARALLEL across the face of the column as shown in Fig. 27.12a. Then another, smaller PARALLEL is clamped near the first one, but against the gib bracket ways. A surface Gage with attached DIAL INDICATOR is stationed on

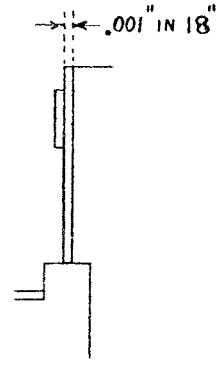

Fig. 27.11(b) Tolerance allowed for parallelism of gib bracket ways to face of column - longitudinal direction.

the PARALLEL, first named, in such a way that the contact point of the instrument bears against the smaller PARALLEL. The surface Gage is moved back and forth and readings are obtained at points (a) and (a'). These readings must be within the tolerance shown in Fig. 27. 12b if the gib bracket way is to be considered parallel to the face of the column. The tolerance allowed should not be exceeded because the more accurately the operation is performed, the less effort is expended later in fitting the associated

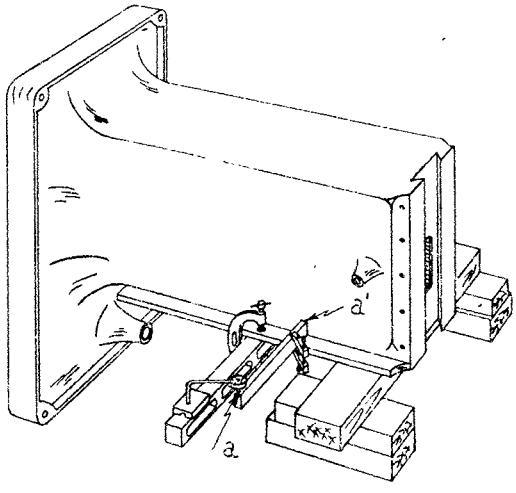

Fig. 27.12(a) Arrangement of apparatus for checking parallelism of bracket ways with face of column - transverse direction.

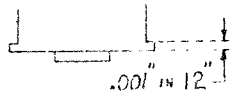

Fig. 27.12(b) Tolerance allowed for parallelism of gib bracket ways to face of column - transverse direction.

gib bracket bearings of the knee.

When working the second gib bracket way, on the opposite side of the column, the same procedure is followed. Usually both surfaces are dealt with together. If all measurements are similar OBJECTIVE NO. 2 is achieved.

OBJECTIVE NO. 3 is fulfilled simultaneously.

NOTE: The importance of maintaining identical dimensions on both gib bracket ways is discussed more fully in Sec. 27.29.
(This completes the rescraping and alignment of the column surfaces. We now turn our attention to the knee member.)

Sec. 27.14
The Knee

The knee member of the horizontal milling machine slides vertically on the column, guided by the column ways, and is adjustable to different levels. This component supports the saddle and guides its movement in a transverse direction.

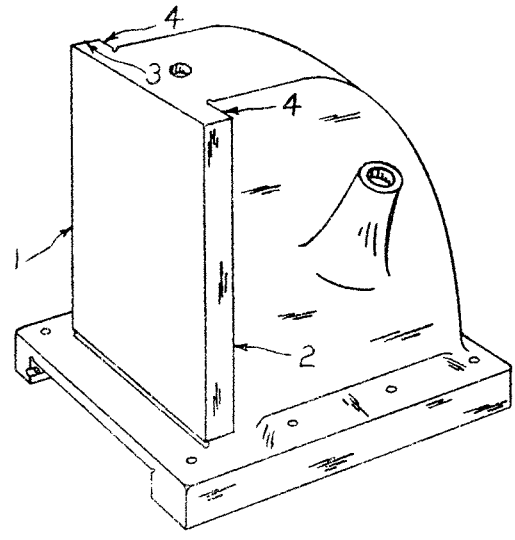

Fig. 27.13(a) View showing surfaces of knee associated with the saddle member (horizontal milling machine)

(1) flat way (2) guiding way (3) gib way (4) gib bracket ways

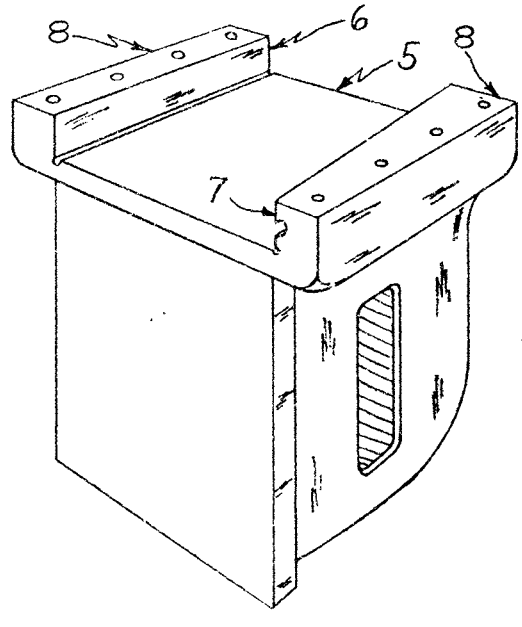

Fig. 27.13(b) View showing surfaces of knee associated with the column member. (horizontal milling machine)

(5) flat slide (6) guided slide (7) tapered gibbed surface (8) gib bracket bearings

Fig. 27.13a and Fig. 27.13b show eight separate surfaces on the knee that are scraped, either to eliminate worn areas and improve surface bearing contact, or to correct the alignment. Of these sur-

faces, only four determine the proper alignment of the knee member. They are denoted by (*) in the following list. When the four surfaces, so indicated, have been scraped to a proper alignment with the column, and the remaining bearing surfaces are scrape-finished also, the knee member is completed.

The surfaces referred to are listed below in the approved sequence for scraping.

GROUP NO. 1 comprises surfaces which are associated with the saddle member, namely:

(*) 1. Flat way of the knee
(*) 2. Guiding way of the knee
3. Gib way of the knee.
4. Gib bracket ways of the knee.

GROUP NO. 2 consists of surfaces which are associated with the column member, viz:

(*) 5. Flat slide of the knee.
(*) 6. Guided slide of the knee.
7. Taper gibbed surface of the knee.
8. Gib bracket bearings of the knee.

Sec. 27. 15
Preparations for Exploratory Examination

Of all the members of the horizontal milling machine, the knee member is the most difficult to scrape to good alignment. There are several reasons for this. In the first place, several alignments must be attained simultaneously. Secondly, it is a heavy and unwieldy member to handle. Thirdly, a rather lengthy routine of operations is required.

The very first move in dealing with the knee is to inspect the various bearing surfaces. This statement hardly needs repeating. Not infrequently, however, an inexperienced scraper neglects this important step. To get a running start, so to speak, he scrapes the flat slide of the knee, or one of the other surfaces, to completion. This plan, though, is as unwise as it is premature. First, it is unlikely that the newly scraped surface would be parallel to the plane of the original surface. (Refer to Sec. 23.20) Secondly, the scraping might actually worsen the existing alignment of one surface to another.

Since direct action is obviously not the wisest course, the proper procedure is to make a survey of what needs to be done. This calls for an Exploratory Examination. It may be advisable for the reader to refresh his memory concerning this subject by rereading Sec. 23.3.

As a part of the survey the operator should gather all pertinent information concerning the present condition of the bearing surfaces. Data, such as the location of areas relatively unused and still showing the original frostings and scraper tool marks, should be made note of for future use. Notice is also taken of the presence of worn portions. Now is the proper time to do this before the surface is altered by the removal of metal.

Having completed these preliminary operations, we now should have a fairly clear and comprehensive picture in mind as to the condition of the worn bearing surfaces. This information will prove useful when correlated with the findings of the Exploratory Examination. In undertaking that survey it will be apparent that only an average indication of alignment is possible because the accuracy of the tests is quite dependent upon the flatness of the surfaces, and for the present this condition is largely wanting.

In this connection, whenever our inspection reveals excessively worn areas it is recommended practice to smooth them down with the scraper tool. This is done to eliminate any noticeable roughness that would make the preliminary tests so inaccurate as to be worthless. Each of the knee surfaces identified in a preceding section by a star (*) is rough scraped a few times, striving not for alignment, but merely to improve flatness. A SURFACE PLATE is used for spotting the flat way of the knee, while a STRAIGHT EDGE is ideal for spotting the guiding way. For spotting the flat slide and guided slide of the knee it is preferable to employ the mateing surfaces of the column as a template.

Sec. 27.16
Exploratory Examination of the Knee

Before proceeding with the Exploratory Examination, it might be well to consider what we are seeking. In other words, "What purpose do we have in mind scrap-

ing this member?" And "What essentials must be satisfied before the member will be passed as acceptable?" The answers to these questions are found by conducting alignment tests on the several surfaces. The requirements pertain to the relationship of one bearing surface to another, as follows:

1. The flat way of the knee to be square with face of column. (Fig. 27.14 shows the tolerance)
2. The guiding way of the knee to be square with face of column. (Alignment tolerance is indicated in Fig. 27.15)
3. The flat way of the knee to be square with the guiding way of column. (Tolerance is shown in Fig. 27.16)

To assure accuracy in the three alignment tests, the surfaces must be clean. Therefore, all traces of marking compound are removed from both the knee

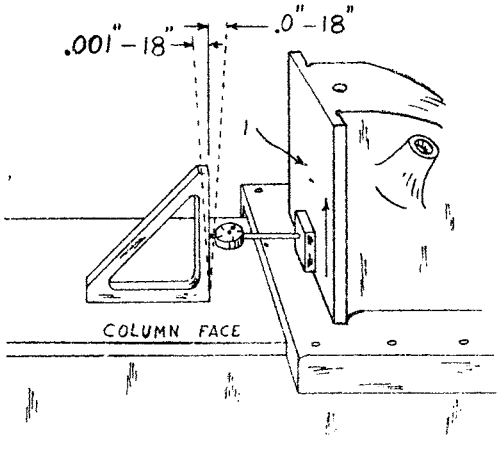

Fig. 27.14 Testing alignment of flat way of knee to face of column. (Knee flat way to be square with face of column) Maximum variation indicated.

(1) flat way

and the column. After placing the knee member on the column, the guided slide of the knee is pushed into full contact with the guiding way of the column. We are now ready to proceed.

Inasmuch as the operations described below seem much more complex when described than when performed, it is advisable for the reader to take the trouble to follow the steps graphically. If

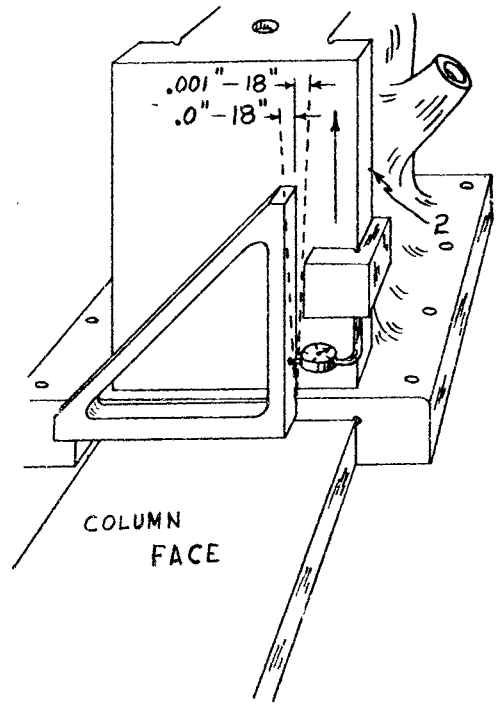

Fig. 27.15 Testing alignment of guiding way of knee to face of column. (Guiding way of knee to be square with face of column) Maximum variation indicated.

(2) guiding way

frequent reference to the figures is made the whole sequence of operations will thereby become more understandable.

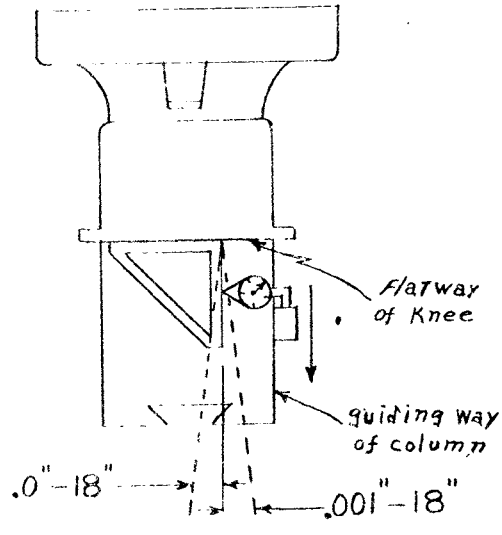

Fig. 27.16 Testing alignment of flat way of knee to guiding way of column. (Flat way of knee to be square with guiding way of column) Maximum variation indicated.

Sec. 27.17
TEST NO. 1 (Refer to Fig. 27.17)

REQUIREMENT for CORRECT ALIGNMENT

Flat way of knee to be square with face of column.

PROCEDURE:

1. Stand a SCRAPED TRIANGLE on the face of column.
2. Hold a Surface Gage with attached DIAL INDICATOR against the flat way of the knee.
3. Move the SCRAPED TRIANGLE into contact with the DIAL INDICATOR and then "zero" the DIAL.
4. Slide the Surface Gage up and down the flat way of the knee the maximum distance possible.
5. If the DIAL averages "minus" while moving "upward" the knee is misaligned. (See Fig. 27.14) The amount of error can be determined by inserting shims between the flat slide of the knee and the face of the column at the positions shown in Fig. 27.18. The appropriate caliper is known to be inserted if the average reading now approximates the requirements shown above.

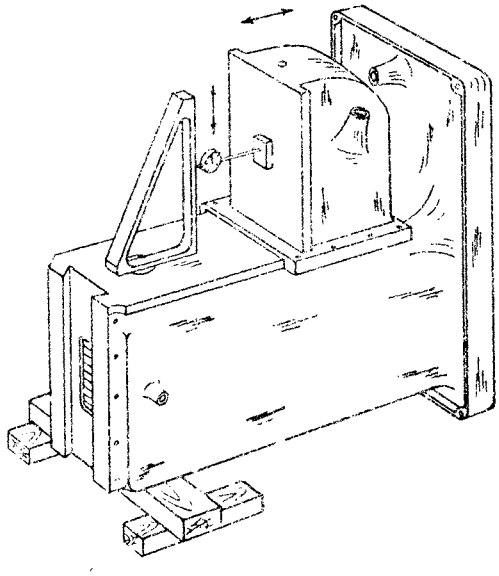

Fig. 27.17 General arrangement of apparatus for checking alignment of flat way of knee to face of column.

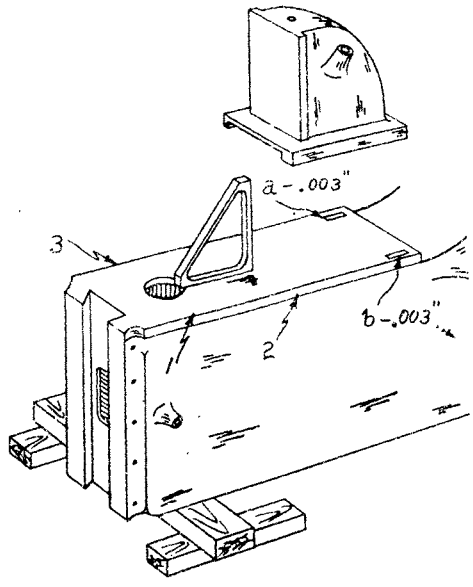

Fig. 27.18 View showing method of inserting shims at "a" and "b" to compensate the misalignment between flat way of knee and face of column. Shim stock approximately 1" x 3" is placed about 1" from edge of column face.

(1) flat way (2) guiding way (3) gib way

6. In case the average DIAL reading is a large "plus" (See Fig. 27.14) when moving "upward," then the knee must be tilted in the opposite direction for proper alignment. We can ascertain the degree of error by the thickness of the shims inserted between the flat slide of the knee and the column face at a position opposite that shown in Fig. 27.18. (This alternative is not shown in any diagram.)

For purposes of illustration let us assume that to obtain the correct alignment of the knee, two shims of .003" thickness must be placed on the column face. One is located on the gib way side, the other on the guiding way side. These shims are shown in proper position at points (a) and (b) in Fig. 27.18.

Sec. 27.18
TEST NO. 2 (Refer to Fig. 27.19)

REQUIREMENT for CORRECT ALIGNMENT

Guiding way of knee to be square with face of column.

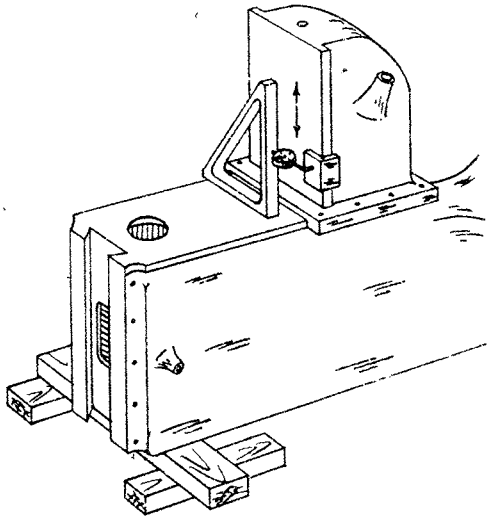

Fig. 27.19 General arrangement of apparatus for checking alignment of guiding way of knee to face of column.

PROCEDURE:

1. Stand the SCRAPED TRIANGLE crosswise on the column face.
2. Hold an indicating jig, with attached DIAL INDICATOR, against the guiding way of the knee.
3. Move the TRIANGLE into contact with the DIAL INDICATOR and "zero" the DIAL.
4. Slide the indicating jig up and down the guiding way of the knee, the maximum distance possible.

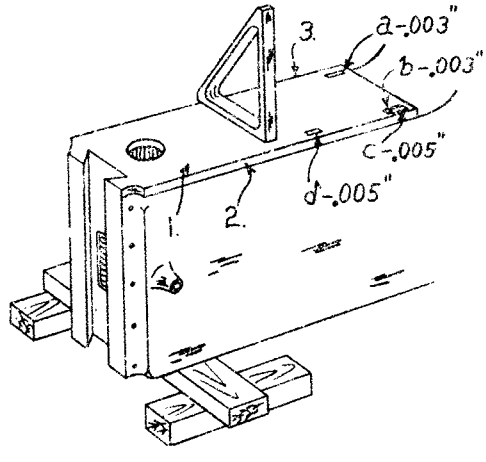

Fig. 27.20 View showing method of inserting shims at "c" and "d" to compensate the misalignment between guiding way of knee and face of column. Observe that the shim stock previously placed is left in position at "a" and "b".

(1) flat way (2) guiding way (3) gib way

5. If the DIAL registers an average "minus" reading when moving "upwards," (See Fig. 27.15) then shims must be inserted between the flat slide of the knee and the face of the column, at the guiding way side of the column, to tilt the knee to an approximately correct alignment. The shim stock is placed as shown at (c) and (d) in Fig. 27.20. In trying to obtain a DIAL reading approaching the requirement indicated above, one must make some allowance for the worn condition of the guiding way of the knee.
6. Should the average DIAL reading be largely "plus" when moving the indicating jig "upward," (See Fig. 27.15) we must shim between the flat slide of the knee and the column face at the gib way side of the column. (This arrangement is not illustrated in any figure but should be easily located because it is opposite the position mentioned in #5 above.)

To clarify the technique of TEST NO. 2, let us assume that a shim of .005" thickness is required to align the guiding way of the knee square with the face of column. Therefore, one shim of .005" is set at (c) on top of the .003" shim previously laid there, making a total thickness of .008" under that corner of the knee. A second shim of .005" is placed farther along the column face as at (d). The placement of all shims so far used is shown in Fig. 27.20.

Sec. 27.19
TEST NO. 3 (Refer to Fig. 27.21)

REQUIREMENT for CORRECT ALIGNMENT

Flat way of Knee to be Square with Guiding way of Column.

PROCEDURE:

1. Place two PARALLELS on the column face to elevate the SCRAPED TRIANGLE.
2. Lay the TRIANGLE on its side across the PARALLELS.
3. Set a SURFACE GAGE with attached DIAL INDICATOR on the face of the column. The edge of the Surface Gage

should be in contact with the guiding way of the column.

4. Keep one surface of the TRIANGLE pressed firmly against the flat way of the knee and at the same time ease the TRIANGLE into contact with the button of the DIAL. Then "zero" the DIAL.
5. Move the Surface Gage back and forth along the guiding way of the column as shown in Fig. 27.21.

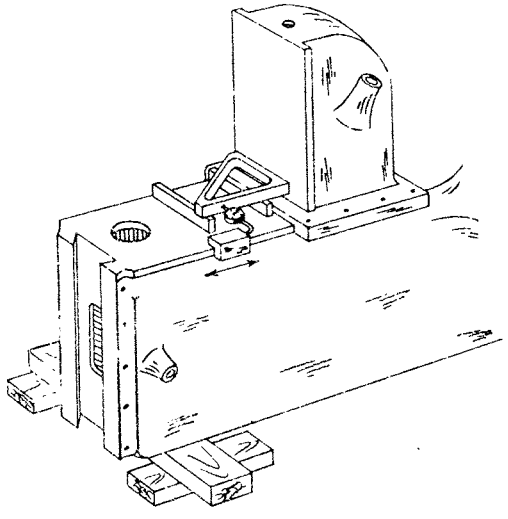

Fig. 27.21 General arrangement of apparatus for checking alignment of flat way of knee to guiding way of column.

6. If the DIAL shows a large "plus" reading while moving "away" from the knee, misalignment of this member is indicated. (See Fig. 27.16) The amount of error can be learned by shimming between the guided slide of the knee and the guiding way of the column at position (e) shown in Fig. 27.22. Repeat the check and increase the caliper of shim stock until the DIAL reading approximates the requirement noted above.
7. In case the reading is "minus" (See Fig. 27.16) when moving the Surface Gage "away" from the knee, shim stock should also be inserted between the guided slide of the knee and the guiding way of the column. However, the difference is that this position would be opposite that at (e), or in other words, farther to the left along the column guiding way, as we view Fig. 27.22. (This possibility is not shown in any of the accompanying figures but the proper location for the shim stock would be at (f).

Continuing the illustration begun in the first and second TESTS, let us assume that a shim of .005" thickness is needed to align the flat way of the knee square with the guiding way of the column. To satisfy the conditions set down in #6, the shim must be placed between the guided slide of the knee and the guiding way of the column at point (e) as shown in Fig. 27.22. This figure also shows the placement of all the shims necessary to align the knee to the column thereby satisfying the three requirements.

CAUTION:

While conducting this test always make certain that the guided slide of the knee is pushed firmly against the guiding way of the column. Additionally, verify that the groove provides ample clearance. See The Light Test in Sec. 18.11.

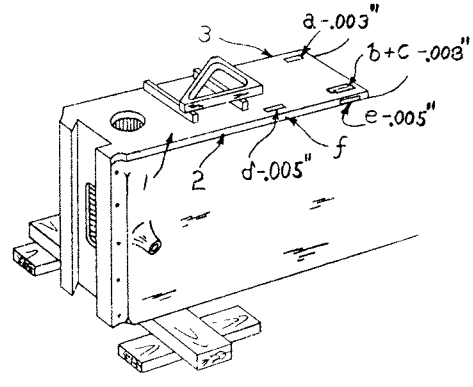

Fig. 27.22 View showing placement of shim at "e" (alternative at "f") to compensate the misalignment between flat way of knee and guiding way of column. Notice that shim stock previously placed at "a", "b", "c", and "d" is retained.

(1) flat way (2) guiding way (3) gib way.

Sec. 27.20
Summarizing the Placement of Shims

When conducting tests No. 1, No. 2, and No 3, thin pieces of shim stock are inserted as follows:

1. Between the flat slide of the knee and the face of the column: Placement is

either on the gib way side or on the guiding way side of the column, or both, depending upon conditions. Furthermore, the position will be either towards or away from the spindle, according to the direction of the tilt.

2. Between the guided slide of the knee and the guiding way of the column: Placement is either towards or away from the spindle, as required by circumstances.

These insertions are made to align the knee as closely as possible to the permissible tolerances shown in Fig. 27.14, Fig. 27.15, and Fig. 27.16. However, in spite of conscientious efforts, the accuracy of the tests may be somewhat in doubt because the worn surfaces induce a rather erratic movement in the DIAL pointer. When the deteriorated condition of the surfaces is taken into account, it is clear why only an average reading can be realized.

As each test is finished, the inserted shims are left in place. When all three tests are completed there may be shims between the knee flat slide and the column face at one or two corners of the knee, if it requires tilting in but one direction. If the knee required tilting for alignment in two directions, there would be shims of varying thickness under three corners. Finally, there may also be a shim between the guided slide of the knee and guiding way of the column, at either one end or the other, if this alignment is not true.

Up to now, we have kept the knee member on the column while the alignment tests were being made and the shims inserted. When the tests are completed, remove the knee and make a rough sketch on a memo pad of the position and thickness of each pile of shim stock. (See Fig. 27.22) From this data we can determine approximately how much metal we must remove from each surface, and how the scraping should be conducted to obtain correct alignment for the knee.

(In practice many experienced operators do not use shims to indicate misalignment but simply keep in mind the error to be corrected. Shims were employed here to clarify the explanation of the scraping procedure on the knee member.)

The ultimate purpose of accumulating all available information is to enable the operator to scrape the surfaces comprising GROUP NO. 1 and GROUP NO. 2, in such a way that they will be finished parallel to the plane of the original factory new surface as well as correctly aligned to the column.

The time consumed in making these tests is well spent because, after the acquired information has been analyzed, we can formulate a working method. Incidentally, the explanation describing the procedure is far more complicated than the performance of the actual work involved. It has taken a dozen or more paragraphs of writing, and six drawings to discuss the procedure of inserting shims and estimating measurements. This is likely to give an exaggerated idea of the difficulty of the job. Fortunately, it is easier to perform than to describe. As experience is gained, the operator may well discard the shims altogether and substitute a memo book and pencil, or a piece of chalk and a board.

Sec. 27.21
Analysis of Information Obtained in Exploratory Examination

From a preliminary examination of the bearing surfaces we observed that wear was present on the flat way, the guiding way, the flat slide, and the guided slide of the knee. Furthermore, TEST NO. 1 disclosed the quantity of shim stock required to correct the alignment in one direction. TESTS NO. 2 and NO. 3 provided additional evidence of misalignment. We know now approximately how much total error is present.

Using this accumulated information, we must determine the quantity of metal that should be removed from each surface, in order to obtain the required surface bearing quality and essential alignments. Here our problem is to estimate how much of the total misalignment each surface is responsible for. A particular misalignment could be entirely corrected by scraping only one affected surface. But a cardinal rule of the

scraping art is to produce a new surface that is parallel to the plane of the original factory surface. To achieve this goal it becomes necessary for the total error in a certain alignment to be divided in proportion to the wear on the several affected surfaces. Therefore, the operator must determine with reasonable accuracy how much to scrape from each surface.

In pro-rating the thickness of metal to be removed from each knee surface, to correct a misalignment, there should be no arbitrary division. Apportioning the error between the flat slide and the flat way on a 50 - 50 basis, and between the guided slide and guiding way on a ratio of say 75 - 25, or a similar pat formula, makes it easy to compute. But it is not necessarily a realistic division. In dividing the scraping between the groups of surfaces, the operator should be governed by just two considerations, namely: First, to produce a surface parallel to the original factory surface. Second, to obtain surfaces which are correctly aligned to the column.

To apportion the work to accomplish these purposes we proceed as follows:

The first thing to do is locate the plane of the original surface. But on a badly worn machine this is not easy. As stated previously, clues are discoverable by an Exploratory Examination of the knee surfaces. The distinctness of the frosting or flaking marks, for example, is a tell-tale sign. Obviously, this information would have to be gathered before any scraping is done which will obliterate the original surface. If nothing definite is learned from these sources then an estimate based on experience is made from the pointers enumerated below.

1 Under normal use the portion of the flat way of the knee farthest from the column will show more signs of wear. This is due to the saddle being positioned oftener towards this end, under normal working conditions.
2. In cases where scraper tool marks remain visible on the surfaces, their clearness and distinctness indicates which portions of the surface are less worn than other parts.
3. A knowledge of the use to which the machine has been put may provide a clue as to its condition. For example, if the machine was used for manufacturing purposes involving an operation wherein the knee remained stationary, while the saddle was run in and out on the knee, obviously the flat slide of the knee would have retained most of its original accuracy. Whatever misalignment there is must be due to the worn condition of the flat way and guiding way of the knee.

We will clarify and expand upon this subject as now we commence the actual scraping of the knee. We will assume in our imaginary case that the bearing surfaces of GROUPS NO. 1 and NO. 2 are about equally worn. Consequently, in the following discussion, treatment is begun with GROUP NO. 1 because this procedure is somewhat more convenient, although under the circumstances, there is no disqualifying reason why the surfaces in GROUP NO. 2 could not be dealt with first. If one group of surfaces displays definite superiority of condition over the other, then it is the better practice to commence with it.

Sec. 27.22
OBJECTIVES: The Flat Way of the Knee

1. To satisfy, in part, the requirement that the flat way of the knee be square with the column face. (Refer to TEST NO. 1, Fig. 27.17)
2. To satisfy, in part, the requirement that the flat way of the knee be square with the guiding way of the column. (Refer to TEST NO. 3, Fig. 27.21)
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

By continuing to use our hypothetical example, we are also able to explain the preferred way of achieving the OBJECTIVES with the minimum of effort. Thus for OBJECTIVE NO. 1 we will assume that, from the evidence gathered, our experience and judgment inclines us to favor reducing the misalignment on a basis that divides the error, 50 - 50 between the flat way of the knee and the flat slide of the knee. In other words, we estimate that this division will most closely restore the surface to a plane

parallel with the original factory surface. Therefore, we will scrape one half the mis-alignment, or .0015", from the flat way. From the findings in TEST NO. 1 the logical procedure to follow, in partially correcting the mis-alignment, is to remove the thicker portion of metal at the back of this surface and tapering to nothing at the front. (See Fig. 27.23.) In other words, a wedge of metal is cut away. This is over and above whatever metal is removed to produce the requisite surface bearing quality. (The balance of the mis-alignment will be corrected by scraping the flat slide of the knee when, in due course, that surface is treated.)

When executing OBJECTIVE NO. 2, we will assume, judging from the information at hand, that it is best to reduce the

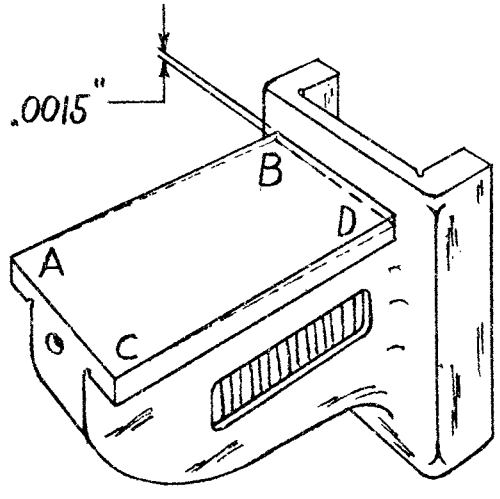

Fig. 27.23 Diagram showing wedge of metal represented by dotted lines (ABCD) to be removed from flat way of knee on the basis of test illustrated in Fig. 27.17.

NOTE: Along (AC) no metal is removed From (AC) to (BD) the wedge tapers to .0015"

indicated misalignment on the flat way of the knee by about .003", or 60% of the total. The excess metal that is removed is in the form of a wedge, thicker proximate to the gib way of the knee, see (c•d) as shown in Fig. 27.24. Whatever thickness of metal is scraped away, is in addition to the quantity removed to obtain the necessary surface bearing quality. (The balance of the misalignment is rectified, subsequently, by scraping the guided slide of the knee.)

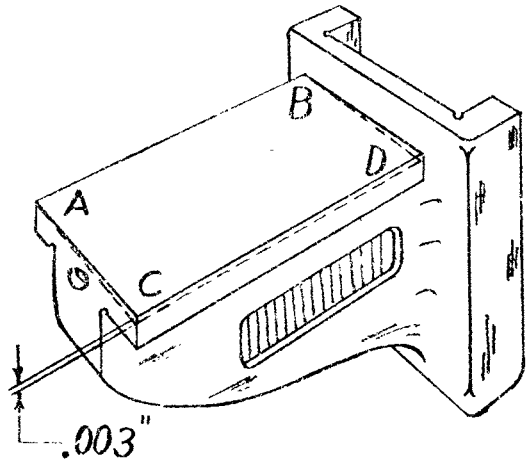

Fig. 27.24 View showing wedge of metal represented by dotted line (BDCA) to be removed from flat way of knee on the basis of test illustrated in Fig. 27.21.

NOTE: Along (AB) no metal is removed From (AB) to (CD) the wedge tapers to .003".

A moment's thought will show how absurd it is to scrape the knee flat way and accomplish OBJECTIVE NO. 1, including the required surface quality, only to destroy this achievement immediately, by scraping the knee flat way in another direction, to obtain OBJECTIVE NO. 2. Therefore, in so far as removal of metal is concerned, we should combine OBJECTIVES NO. 1 and NO. 2 as shown in Fig. 27.23 and Fig. 27.24. That is, we will scrape the surface so as to arrive at a resultant of the two requirements. This is illustrated in Fig. 27.25. Although the alignment procedures are somewhat complex, the actual scraping and spotting technique is quite simple and is accomplished by conventional means. The knee member is placed on either a bench or a turn table for convenience. Next the flat way of the knee is spotted by a SURFACE PLATE. If the available tool is somewhat undersize it would be alternated with a STRAIGHT EDGE.

Occasionally, it is expedient to replace the knee on the column and repeat the tests shown in Fig. 27.17 and Fig. 27.21. Since the surface has been improved by scraping, the tests become progressively more accurate as a result.

When we have removed the amount of metal called for, we will have completed OBJECTIVES NO. 1 and NO. 2. At this

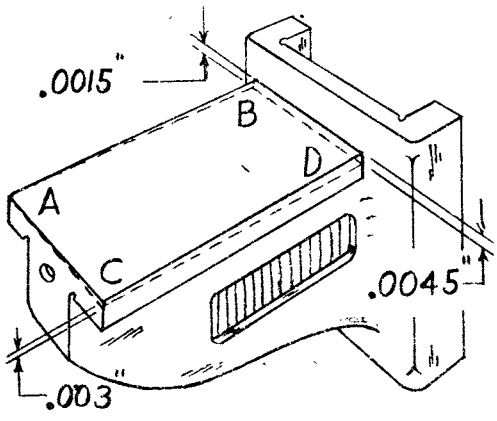

Fig. 27.25 Diagram showing the result of combining the requirements indicated in Fig. 27.23 and Fig. 27.24. Thus to accomplish the alignment the removal of metal is performed as follows: From position

(A) No metal is removed; (A) to (C) tapers to .003"; (A) to (B) tapers to .0015"; (A) to (D) tapers to .0045".

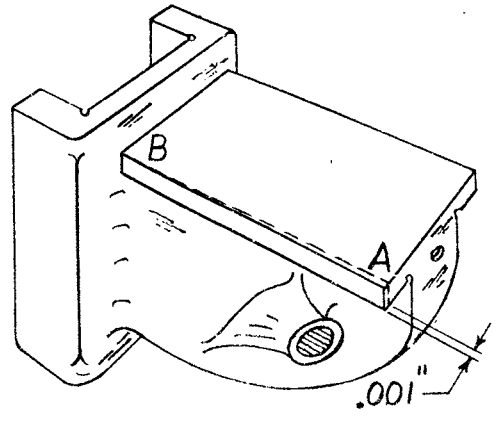

Fig. 27.26 Dotted line shows limits of wedge of metal to be removed from guiding way of knee on the basis of test represented by Fig. 27.19. Wedge tapers from nothing at (B) to .001" at (A).

same time the surface bearing quality indicated in OBJECTIVE NO. 3 should also be secured and distributed uniformly over the entire flat way.

Sec. 27.23
OBJECTIVES: The Guiding Way of the Knee

1. To satisfy, in part, the requirement that the guiding way of the knee be square with the column face. (Refer to TEST NO. 2, Fig. 27.19)
2. To be square with the flat way of the knee.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

Once again basing our judgment on the accumulated evidence, we decide that the guiding way is responsible for only about 20%, or .001", of the total misalignment amounting to .005". Thus we will remove a wedge of metal from the guiding way of the knee by scraping .001 deeper at the front of this surface than at the back, satisfying OBJECTIVE NO. 1. See Fig. 27.26. (The balance of the misalignment will ultimately be corrected by scraping the flat slide of the knee.)

A STRAIGHT EDGE employed for spotting purposes will help keep this surface flat and true. To maintain the guiding way square with the flat way of the knee, as required by OBJECTIVE NO. 2, a RIGHT ANGLE TEMPLATE is used.

After a few cycles of spotting and scraping, it is advisable to replace the knee on the column and repeat TEST NO. 2 shown in Fig. 27.19.

It is good practice to deal concurrently with the guiding way and the flat way of the knee. This is recommended so as to reduce the number of times the knee must be positioned on the column for Alignment Tests to determine scraping progress.

While OBJECTIVES NO. 1 and NO. 2 are being attained, the desired quality of bearing surface, suggested by OBJECTIVE NO. 3 should also be secured.

Sec. 27.24
OBJECTIVES: The Gib Way of the Knee

1. To be parallel to the guiding way of the knee.
2. To be square with the flat way of the knee.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The principal requirement for this surface is to keep it parallel with the surface previously scraped, namely, the guiding way. Therefore, while scraping the gib way to a condition of flatness, occasional checks for parallelism are made. For this purpose an indicating jig with attached DIAL INDICATOR is used. Ref-

erence to Sec. 16.14 will provide further details.

The operator will find the RIGHT ANGLE TEMPLATE very useful for holding the gib way at the required. 90° to the flat way of knee. Care should be exercised to secure this condition, otherwise the gib piece on the saddle member will be quite difficult to fit. (For reasons refer to Sec. 17.27.)

All OBJECTIVES are effected simultaneously.

Sec. 27.25
OBJECTIVES: The (Two) Gib Bracket Ways of the Knee

1. To maintain an equal distance between both bracket ways and the flat way of the knee.
2. To be parallel with the flat way of knee.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

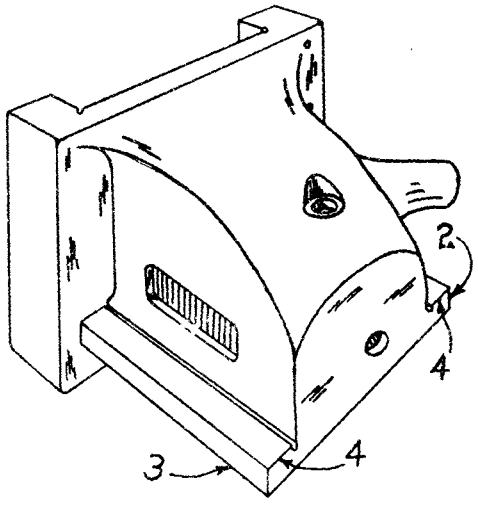

Fig. 27.27 View showing gib bracket ways of knee (2) guiding way (3) gib way (4) gib bracket ways

PROCEDURE:

There are two gib bracket ways which must be scraped parallel to the flat way of the knee. (See Fig. 27.27) The customary tools, STRAIGHT EDGE and RIGHT ANGLE TEMPLATE, are used for spotting these surfaces. Frequent measurements with a micrometer, at both ends of each gib bracket way, will help keep these surfaces the same distance from the flat ways, thereby satisfying OBJECTIVE NO. 1.

To secure OBJECTIVE NO. 2 the operator is urged to employ the same procedure in checking the parallelism of the gib bracket ways of the knee as was used for the gib bracket ways on the column. The technique of manipulating PARALLELS, DIAL INDICATOR etc. is thoroughly explained in Sec. 27.13.

All OBJECTIVES are attained simultaneously.

NOTE: Before scraping the gib bracket ways, it is essential to inspect the grooves for clearance. If too small, or too shallow, they must be enlarged.

* * * * * *

This completes all the knee surfaces classified in GROUP NO. 1. All the surfaces have been scrape-finished, and if the work has been properly done and the OBJECTIVES satisfied, these surfaces are completed. In concluding this portion of the work a partial correction of the misalignment of the knee member, with respect to the column, has been effected.

Now we commence the scraping of surfaces in GROUP NO. 2 to bring the knee member to final alignment with the column.

Sec. 27.26
OBJECTIVES: The Flat Slide of the Knee

1. Flat way of the knee to be square with the face of the column.
2. Guiding way of the knee to be square with the column face.
3. To be fitted to the column face with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

After coating the column face with marking compound, so it can serve as a spotting template, the knee member is placed on it. By moving the knee member back and forth, the compound transfers to the flat slide of the knee. A minimum movement is recommended, and it should be limited to the lower part of the column. This precaution is advisable so that, in case the column face is scratched by the spotting, the blemishes will at least be confined to the portion of the column usually screened by

the knee during normal operation, and therefore be less noticeable.

Periodically while the knee is in position on the column for spotting purposes, it is a good plan to conduct alignment tests to determine the progress of the scraping effort. In this connection it is worthy of note that, although the flat slide is being discussed and is being treated, OBJECTIVE NO. 1 is phrased to pertain to the flat way of the knee. Furthermore, the actual alignment test of this surface is made from the scrape-finished surface of the knee flat way to the column face, as shown in Fig. 27.28. However, the misalignment, if any, is rectified by scraping the knee flat slide, until requirements are met. The unilateral tolerance allowed is also shown in the figure mentioned.

OBJECTIVE NO. 2 follows the same plan, namely: The test for alignment is conducted from the scrape-finished knee guiding way to the column face. (See Fig. 27.29) Any error in alignment is also corrected by scraping the knee flat slide. The unilateral tolerance permitted is given in the figure above mentioned.

In order to speed the work, skilled scraping operators always combine into one resultant, the several operations required to attain these separate OBJECTIVES. By working this way, the correct alignment required by OBJECTIVES NO. 1 and NO. 2 is effected jointly with the desired bearing surface suggested in OBJECTIVE NO. 3.

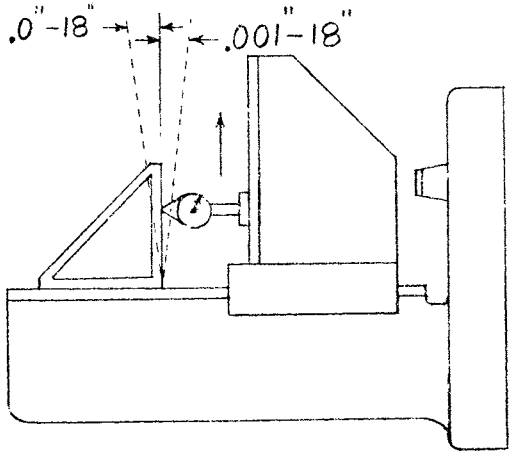

Fig. 27.28 Method of testing alignment of flat way of knee to face of column. (Side View) The maximum reading should be seen as the DIAL INDICATOR moves in the direction shown by the arrow.

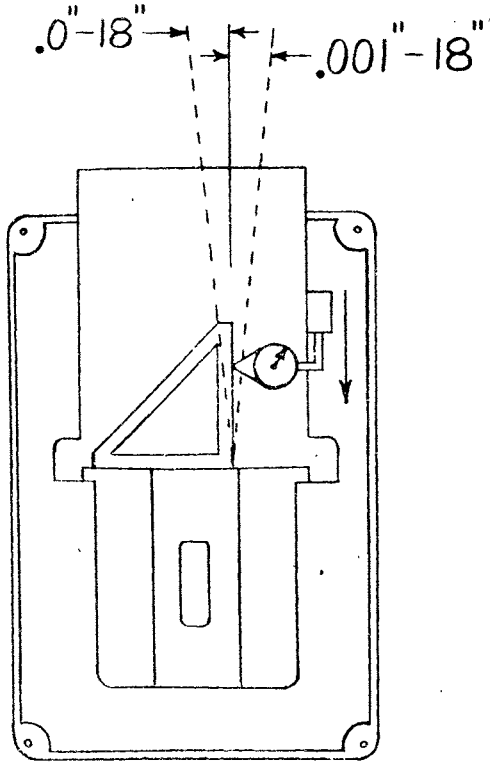

Fig. 27.29 Checking the alignment of guiding way of knee with face of column. (Top View) The maximum reading should be observed as the instrument moves in the direction indicated by arrow.

A low bench or scraping turn-table is a great convenience to the operator when tackling this unwieldy member. When conditions permit, the occasional application of a SURFACE PLATE or STRAIGHT EDGE to spot the knee flat slide expedites the job.

Sec. 27.27
OBJECTIVES: The Guided Slide of the Knee

1. To be square with the flat slide of the knee.
2. Flat way of the knee to be square with the guiding way of the column.
3. To be fitted to the guiding way of the column with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

A STRAIGHT EDGE and a RIGHT ANGLE TEMPLATE are used for spotting. The one will indicate flatness, the other will help keep the guided slide of the knee square with the flat slide, as required by OBJECTIVE NO. 1.

Operations will be facilitated if, occasionally, the guiding way of the column is employed as a spotting template. This can be done easily by applying a coat of marking compound thereto. Then the guided slide of the knee is shoved tightly against the guiding way of the column. Next the knee member is pushed back and forth a few times. This causes the medium to transfer to the high spots on the guided slide of the knee. The markings are scraped from this surface in the customary manner.

As the surface approaches the scrape-finished stage, more reliance must be placed on the mateing member as a spotting template to insure that the guided slide of the knee is properly fitted. In other words, OBJECTIVE NO. 3 being more important takes precedence over OBJECTIVE NO. 1.

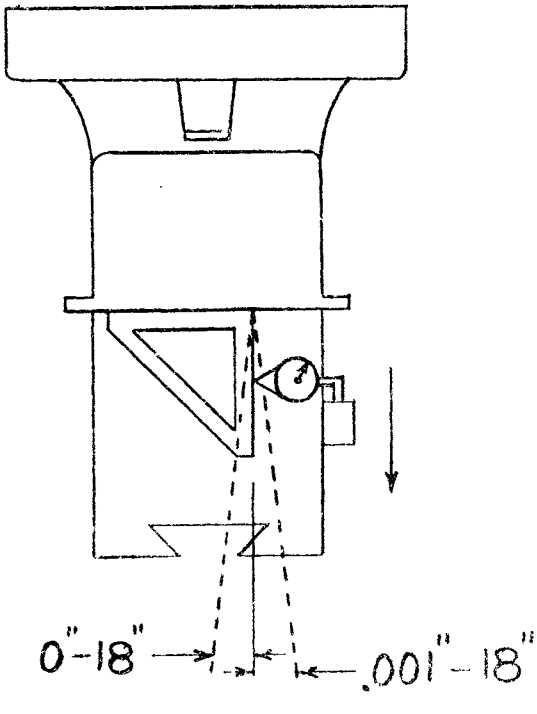

Fig. 27.30 Checking the alignment of the flat way of knee with guiding way of column. (Top view) The maximum reading should be observed as the DIAL INDICATOR moves in the direction shown by arrow.

At intervals, while the member is being spotted on the column, it is a good plan to ascertain the progress in alignment. This measurement is conducted from the scrape-finished surface of the knee flat way to the guiding way of column, as shown in Fig. 27.30. Whatever misalignment still remains, is eliminated by scraping the guided slide of the knee, until OBJECTIVE NO. 2 is fulfilled. The permissible unilateral tolerance is shown in the above mentioned figure.

The surface bearing quality required in OBJECTIVE NO. 3 should be achieved at the same time.

It might be apropos to point out that it is standard practice for experienced scraping operators to work jointly on the flat slide and the guided slide of the knee. This cuts in half the number of times the knee member must be placed on the column, either to spot the surfaces, or to conduct alignment tests. If this system is followed, the several OBJECTIVES, of the flat slide and the guided slide of the knee, are completed together.

Sec. 27.28

OBJECTIVES: The Tapered Gibbed Surface of the Knee (The knee gib will be a tapered gib)

1. to be square with the knee flat slide.
2. To have a surface quality of 4 - 5 bearing spots per square inch.

PROCEDURE:

A RIGHT ANGLE TEMPLATE is a very appropriate tool for maintaining the gibbed surface, square with the knee flat slide. (See Fig. 27.31) This requirement is essential so that the tapered gib, described later, may be more easily fitted. (Refer to Sec. 17.27 for a discussion of the reason.)

The frequent application of the STRAIGHT EDGE for spotting will help keep the gibbed surface flat. Additionally, it will promote the formation of a satisfactory bearing surface. The bearing quality need not be as good as on other surfaces of the knee since the gibbed surface will have only a stationary (fixed) contact with the gib piece.

The groove should be inspected for clearance if this has not already been done. We mention this again because it

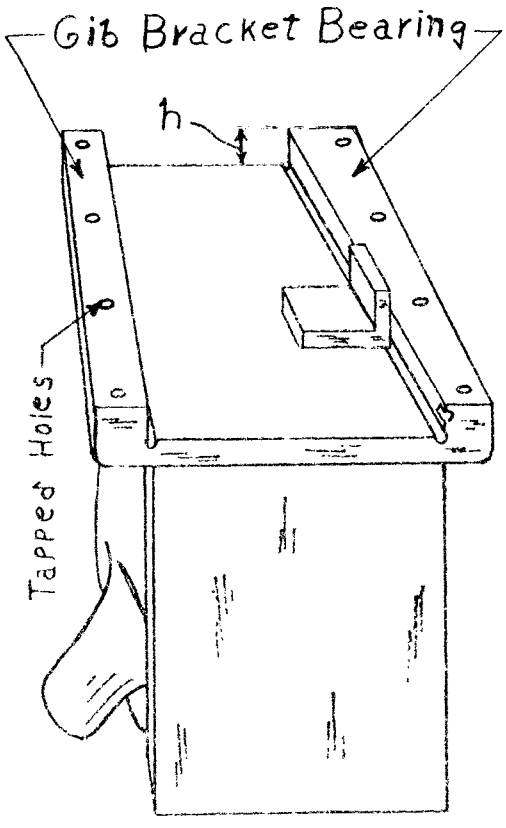

Fig. 27.31 Spotting the tapered gibbed surface of knee with a Right Angle Template.

(h) distance from flat slide to gib bracket bearings.

is so very important. The gibbed surface is scraped most conveniently by laying the knee member on a bench.

Reference to Fig. 27.31 reveals that the gibbed surface is tapered. Ordinarily, in scraping this surface it is not necessary to preserve the same taper as originally produced at the factory, because in rescraping a knee, a new tapered gib piece is nearly always called for. It is enough merely to scrape the gibbed surface to an acceptable plane of flatness allowing any chance taper to evolve that may. The new gib piece is fitted then to the new taper.

On the other hand, under some circumstances the original gib may be refitted. This is possible provided it has sufficient surplus thickness to be fitted to the expanded gib slot which was enlarged by scraping the several surfaces affecting its size. In that event it is advisable to preserve the original taper. This saves work all around.

NOTE: A gibbed surface has a stationary contact and therefore should require but little scraping unless warping has occurred.

Sec. 27.29
OBJECTIVES: The Gib Bracket Bearings of the Knee

1. To be parallel with the knee flat slide.
2. The height of the gib bracket bearings, as measured from the knee flat slide, to equal the thickness between the column face and the column gib bracket ways, plus an allowance for oil film.
3. To have a surface quality of 4—5 bearing spots per square inch.

PROCEDURE:

Before proceeding with the scraping on these surfaces, it is best to check the condition of the tapped holes. (Refer to Fig. 27.31) If the threads are stripped, the holes should be redrilled and tapped for the next larger size. Countersink all holes to prevent raising burrs when the gib brackets are bolted on. All of this work is done with the knee member blocked up on the floor or bolted to a scraping table as represented in Fig. 27.32.

A SURFACE PLATE large enough to span between the bracket bearings is preferred for spotting the surfaces. If unavailable, a STRAIGHT EDGE is used.

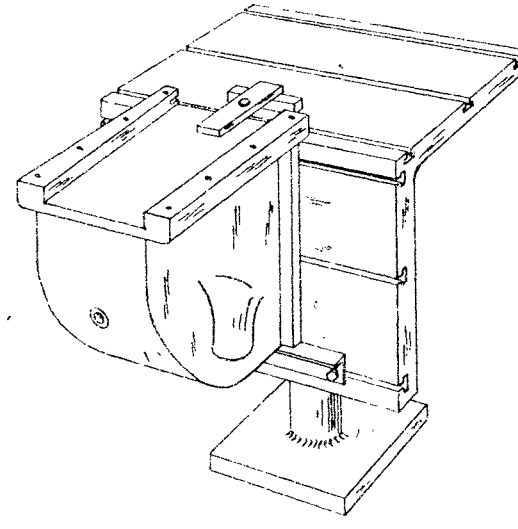

Fig. 27.32 View showing method of attaching knee to a scraping turn table.

When the markings appear uniform from side to side, and end to end on both surfaces, parallelism between these surfaces is indicated. This condition, incidentally, will insure an area contact between the gib brackets when they are bolted on, and the gib bracket ways of the column.

To check for parallelism with the flat slide a depth micrometer may be utilized. Measurements made from the gib bracket bearing surface to the knee flat slide through distance "h" (Fig. 27.31) will, if identical at all four corners, indicate parallelism thus satisfying OBJECTIVE NO. 1.

The measurement "h" must be equal to the distance between the column face and the column gib bracket ways, plus .0005" to .001" for clearance and oil film. Work is continued on the bracket bearings of the knee until this dimension is obtained. This satisfies OBJECTIVE NO. 2.

If through some mishap these surfaces are overscraped and this dimension cannot be met, shims must be inserted between the gib bracket bearings and the gib brackets of the knee. This will build "h" to the required height. Distance "h" should be uniform at all points along the knee bracket bearings (OBJECTIVE NO. 2) so that the gib brackets will bear evenly against the column gib bracket ways. Otherwise rigidity is lost.

All OBJECTIVES must be concluded together.

Sec. 27.30
OBJECTIVES: The Gib Brackets of the Knee

1. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The function of the gib brackets is to secure the knee member to the column member. Two brackets are provided for this purpose. They are of heavy construction and, when solidly bolted to the gib bracket bearings, become an integral part of the knee member. (See Fig. 27.33)

Only one surface of the gib brackets is scraped. This is the one that bears partly against the column gib bracket way and partly against the gib bracket bearing of the knee. Since the portion, bearing on the column gib bracket way is a sliding contact, a surface quality of about 10 - 15 bearing spots per square inch will be required. On the other hand, the portion having fixed contact with the

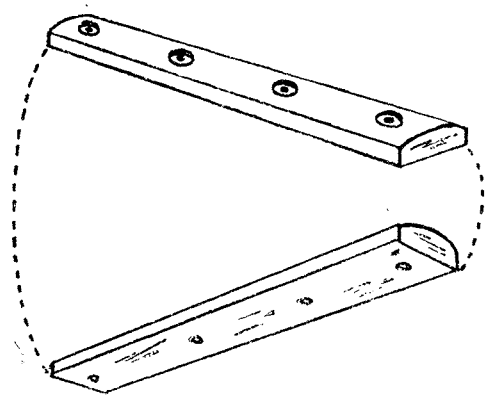

Fig. 27.33 View of gib brackets.

bracket bearing of the knee requires only the minimum quality. For practical reasons, the entire scraped surface of the bracket piece is usually given the same uniform bearing.

The scraped surface of each gib bracket should be square with the axis of the bolt holes. However, if these surfaces are produced with a slight tilt with respect to the axis, it is acceptable because it is usually compensated for by the play in the bolt holes. Excessive tilt, though, is undesirable as it will not allow the head of the bolt to seat itself.

Sec. 27.31
OBJECTIVES: The Tapered Gib Piece of the Knee

1. To be fitted to the gibbed surface of knee with a surface quality of 4 - 5 bearing spots per square inch.
2. To be fitted to the column gib way with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

It is often necessary when rescraping the knee member to make a new tapered gib piece to replace the original one. The old gib may not be badly worn but nonetheless replacement is necessitated. For example, in reconditioning a machine, considerable metal may be scraped from

the surfaces that determine the width of the opening for the gib. Consequently, when the aperture becomes too large, the old gib piece is too thin to fit the expanded opening. In other words, the capacity of a tapered gib for adjustment is limited. This is particularly true when the taper per inch is small.

The first step in producing a new tapered gib is to ascertain the required taper. Fig. 27.34 shows one method of obtaining this information from the knee member by utilizing an indicating jig with attached DIAL INDICATOR. The subsequent steps are fully explained in Sec. 17.17 and Sec. 17.18. Work on this component is concluded when it is well fitted as required by OBJECTIVE NO. 1 and OBJECTIVE NO. 2.

NOTE: In practice the tapered gib piece should be brought close to completion but not actually finished until the Sliding Member Test, which follows immediately, is performed. The test mentioned verifies the parallelism of the several ways of the column.

Sec. 27.32
Testing the Ways of Column for Parallelism

Now is the appropriate time to recheck the parallelism of the column ways with the mateing member. This operation is conducted in two steps. First, the gib bracket ways of the column are tested for parallelism with the column face. Second, the gib way of the column is tested for parallelism with the guiding way.

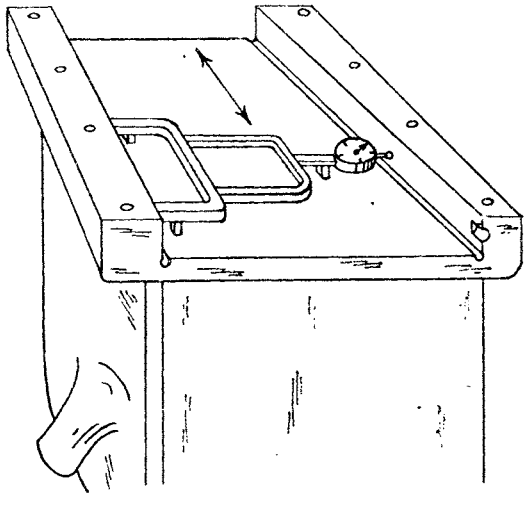

Fig. 27.34 Method of measuring the taper on gibbed surface showing application of indicating jig and DIAL INDICATOR.

To start the first check, the column is carefully cleaned and freshly oiled. Then the knee is cleaned thoroughly and placed on the column. The gib brackets are now bolted to the knee. Next the guided slide of the knee is pressed firmly against the guiding way of the column. Simultaneously, the knee is pushed the entire length of the column. If the operator feels any variation in the force that is required to slide the knee from end to end, the gib bracket ways are not parallel to the column face.

If the parallelism of the column ways is within the limits indicated in Fig. 27. 11b, then no appreciable change in resistance will be felt while moving the knee. On the other hand, any noticeable variation should be carefully investigated to discover if it is important enough to result in excessive looseness or binding of the knee. Either condition would indicate that the gib bracket ways of the column were previously incorrectly gaged. In other words, they are not parallel to the column face.

This misalignment must be corrected before proceeding further. The OBJECTIVES listed in Sec. 27.13 must be satisfied.

If no error is detected in this first phase, step two is commenced. In this operation the semi-finished gib piece is inserted in the gib slot and adjusted for sliding tension. The knee is again pushed the full length of the column. Should resistance be felt enroute, it signifies that the gib way of the column is not parallel with the guiding way. In short, the tolerance allowed in Fig. 27.10b has been exceeded. This error must be corrected before the gib piece can be scrape-finished. To that end the OBJECTIVES listed in Sec. 27.12 must be satisfied.

The already established alignment of the knee flat way and guiding way will not be affected by measures taken to rectify the non-parallelism of the surfaces just discussed.

NOTE: This would be a good time to touch up the ways of the column and the slides of the knee should the appearance of these bearing surfaces indicate that this might be desirable. (Refer to Sec. 19.12)

Sec. 27.33
Frosting or Flaking the Column

Having verified the parallelism of the column ways and the accuracy of the knee alignments, our next step is to decide if the column is to be decorated. The lubrication of the machine is somewhat aided by the addition of the oil retaining frosting marks, and it is generally presumed that its sales value is enhanced. Consequently, a choice must be made whether the scraping tool marks are to be retained or a decorative pattern applied to the column. If the decision is to decorate, the member is cleaned thoroughly. Then a careful inspection of all surfaces is made with a view to locating scratches, nicks, and other blemishes. A careful rereading of Sec. 20.1 will be helpful in determining the proper treatment for each kind.

It is good practice to flake (or frost) the various surfaces of the column in the following order.

1. The gib bracket ways.
2. The guiding way.
3. The gib way.
4. The face.

The decorative work can be performed more quickly and conveniently if the working surface is uppermost. Consequently, operations are facilitated if the column is turned from position to position as required.

There are two reasons why the most conspicuous surface on the column, the face, is decorated last of all. First, the operator, while working a pattern into the gib bracket ways and the other two surfaces, will have developed a rythm or "feel" with his frosting tool. Thus by the time the face is ready for decoration, the operator will have steadied down, and a higher degree of uniformity is attainable. Second, this routine is adopted so that remedial measures may be taken, should the face be scratched accidentally while treating the other surfaces. Since the face of the column is most exposed to view, it should receive the operator's most careful attention.

CAUTION:

1. When ready to apply the decorative marks by hand, only one pattern should be selected for the entire machine.
2. An operator should not attempt either to flake or to frost a large machine unless he has had considerable experience.
3. The prime essential of GOOD DECORATION, either frosting or flaking, is uniformity in the marks. Decorating a large machine is a tedious job and fatigue contributes heavily to disappointing results.

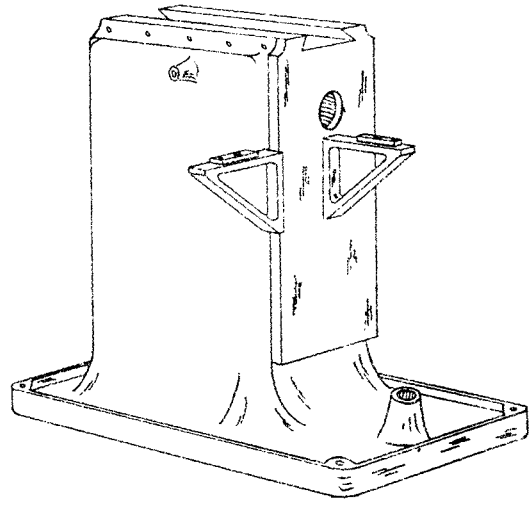

Fig. 27.35 Leveling the column of a horizontal milling machine.
(1) TRIANGLE pressed against the face. Tolerance .0005" per foot.
(2) TRIANGLE pressed against guiding way. Tolerance .0005" per foot.

Sec. 27.34
Erecting the Column

Upon completion of the frosting, the column can be erected and leveled. Fig. 27.35 shows the process. A SCRAPED TRIANGLE is held alternately against the face of the column and the guiding way, and a PRECISION LEVEL is laid on the TRIANGLE in the manner shown. The bubble must be centered in both positions

to indicate levelness. When the need for it is indicated, shims are driven under one or more corners of the base. Incidentally, it is essential that an instrument of at least ten seconds accuracy be used for leveling operations on this casting. Leveling of all machine tools should be conducted with an instrument having an accuracy commensurate with the required precision.

Sec. 27.35
Confirming the Alignments

After leveling the column, the knee member is positioned on the elevating screw and the elevating hand wheel is attached. The gib brackets are bolted to the knee. Next the tapered gib is inserted and adjusted for sliding pressure by moving the knee up and down the column. At this time, with the column erected and leveled, and the knee in operating order, the final Alignment Tests for the knee should be conducted.

Fig. 27.36a shows the method of testing the alignment of the flat way of knee to face of column. The permissible tolerance is indicated in Fig. 27.36b.

In Fig. 27.37a is shown the set up for testing the alignment of flat way of knee to guiding way of column. Fig. 27.37b represents the allowed tolerance.

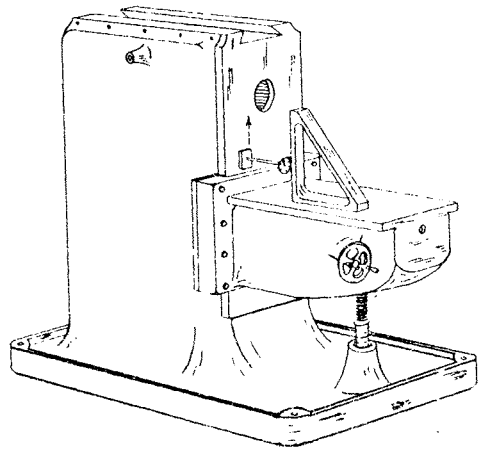

Fig. 27.36(a) General arrangement for testing alignment of flat way of knee to face of column

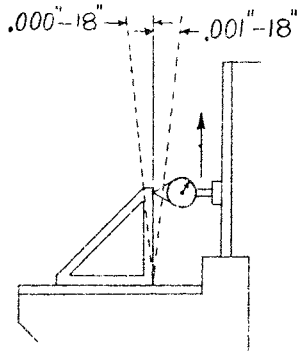

Fig. 27.36(b) Flat way of knee to be square with column face. Tolerance max. .001" in 18". (Low point at rear)

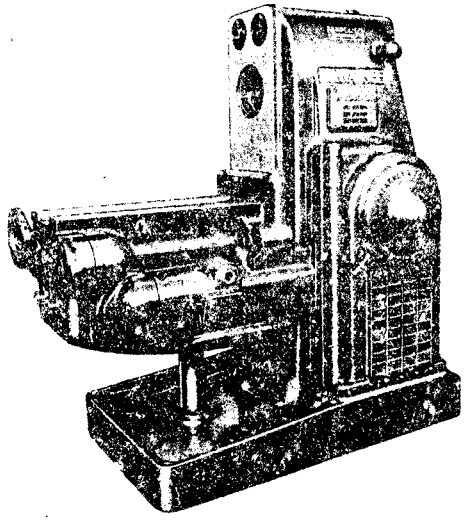

PLATE 43. Knee unit mounted on column - horizontal milling machine. (Courtesy - Kearney & Trecker Corp.)

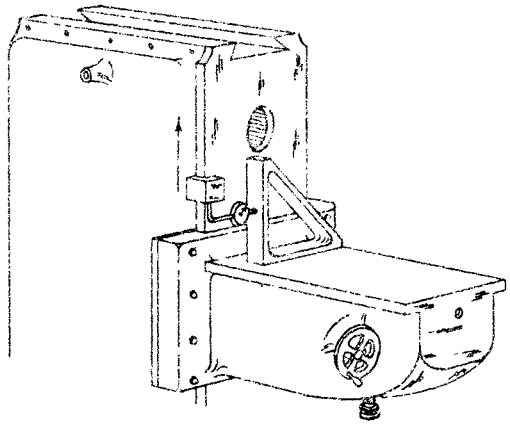

Fig. 27.37(a) Method for testing alignment of flat way of knee with guiding way of column.

To check the alignment of the guiding way of knee to the face of column the arrangement illustrated in Fig. 27.38a is employed. The tolerance is given in Fig. 27.38b.

Before conducting the three tests shown, it is advisable to eliminate slack in the assembly by raising the knee with one or two revolutions of the handwheel.

In case the tolerance, in either of the Alignment Tests represented in Fig. 27.36a or Fig. 27.37a is exceeded, then the knee flat way must be rescraped before fitting the mateing member i.e. the saddle. Moreover, since the relationship of the other ways of the knee was keyed to the knee flat way, any alteration of its surface will, as a matter of course, require the realignment of the other ways of the knee to conform to the new plane. Should this become necessary the amount of metal removed, to correct some slight

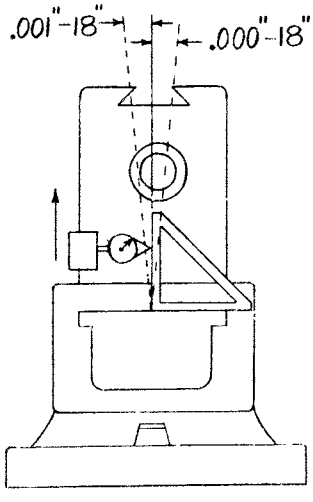

Fig. 27.37(b) Flat way of knee to be square with guiding way of column. Tolerance max. .001" in 18".

error will be small. Therefore, the knee can remain in position on the column while the work is done.

Similarly, if the tolerance in the alignment test illustrated in Fig. 27.38a is exceeded, the guiding way of the knee must be rescraped to remedy the misalignment. The gib way would then also have to be rescraped to be parallel to the altered plane of the guiding way.

It is advisable to perform all three tests consecutively and, when errors in alignment are noted, to take corrective

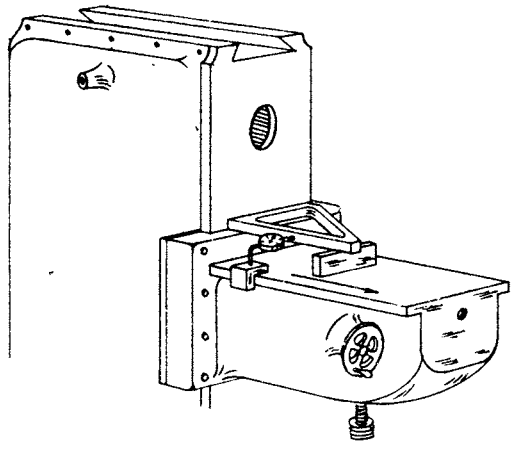

Fig. 27.38(a) Testing guiding way of knee for alignment with face of column.

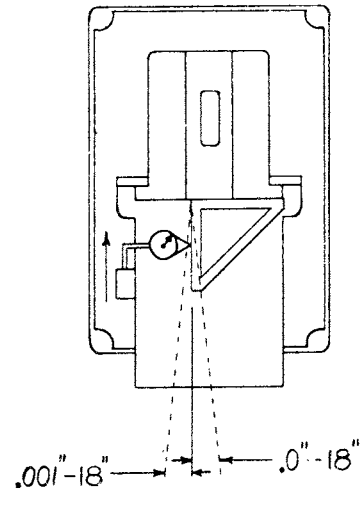

Fig. 27.38(b) Guiding way of knee to be square with column face. Tolerance max. .001" in 18".

measures on all affected surfaces. On the other hand, should the tests prove the alignments satisfactory, the knee member is completed, in so far as its alignment to the column is concerned.

Sec. 27.36
The Over Arm Support

The over arm support, located on the top of the column, is a construction feature on several types of horizontal milling machines. Its function is to support and guide the over arm member. In the example, represented in Fig. 27.39, a

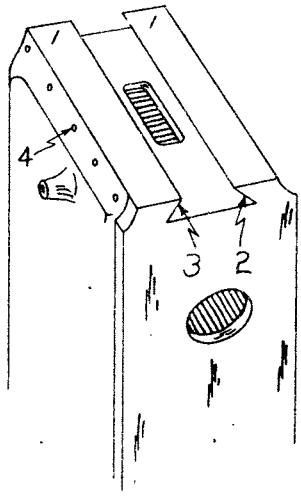

Fig. 27.39 The over arm support of horizontal milling machine.

(1) flat ways (2) angular guiding way (3) angular gibbed surface (4) tapped holes

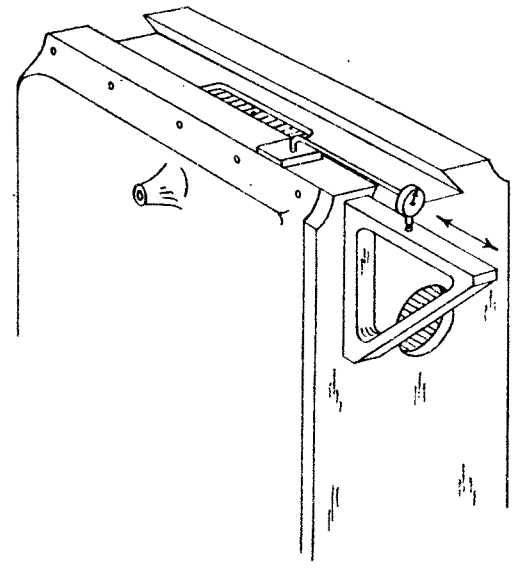

Fig. 27.40 Disposition of apparatus for checking alignment of flat ways of over arm support to face of column. Tolerance max. .001" in 18".

dovetail is used as the form of bearing surface.

The surfaces comprising the over arm support are scraped in the same order that they are enumerated, viz:

1. The (two) flat ways.
2. The angular guiding way.
3. The angular gibbed surface.

Sec. 27.37
OBJECTIVES: The Flat Ways of the Over Arm Support

1. To be square with the face of the column.
2. To be square with the guiding way of column.
3. To have a surface quality equivalent to 10 - 15 bearing spots per square inch.

PROCEDURE:

The flat ways of the over arm support lend themselves to convenient spotting with a SURFACE PLATE or STRAIGHT EDGE. It is standard practice to alternate these tools.

As the scraping proceeds, occasional tests are made for alignment. Alternative tests for OBJECTIVE NO. 1 are shown in Fig. 27.40 and Fig. 27.41. (See NOTE) Either of these methods accomplishes the

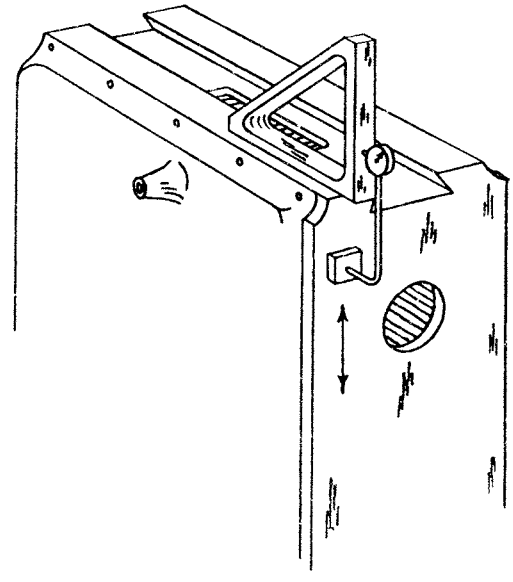

Fig. 27.41 Alternative arrangement of tools for testing alignment of flat ways of over arm support to face of column. Tolerance max. .001" in 18".

same purpose. The method illustrated in Fig. 27.41 is favored because it may be performed easily by a single workman using the following set up:

A SCRAPED TRIANGLE is placed on the flat way as shown. Then the operator moves the Surface Gage with attached DIAL INDICATOR, up and down the col-

umn face meanwhile keeping the DIAL button in contact with the TRIANGLE. This method is also more accurate because when held vertically, there is less tendency for the long extension arm of the Surface Gage to vibrate, or sag.

Fig. 27.42 shows the test for OBJECTIVE NO. 2. In this case the SCRAPED TRIANGLE is laid cross-wise on the flat ways. The Surface Gage with attached DIAL INDICATOR is moved up and down the guiding way of the column. The contact point of the instrument rides against the TRIANGLE.

In all alignment tests the desired reading should be zero-zero at the extremities, modified by the tolerance noted in the Figures. The flat ways are judged completed when the OBJECTIVES are attained simultaneously.

NOTE: An equivalent wording for OBJECTIVE NO. 1 could be "(Flat ways) to be parallel to axis of spindle" Phrased in this language, a different set up is called for. For example, after inserting a test bar in the spindle it is turned so as to place the mean position of eccentricity error at the vertical diameter. The Surface Gage can be set on either flat way. A long arm with attached DIAL is curved down from the Surface Gage to the bar. Keeping the DIAL button in contact, the apparatus is traversed along the bar to obtain readings. This procedure is subject to even more unsteadiness in the arm supporting the instrument than the method shown in Fig. 27.40. For this reason it is preferable to align the flat ways to the column face because that is a more convenient check point and under the circumstances provides more accurate readings.

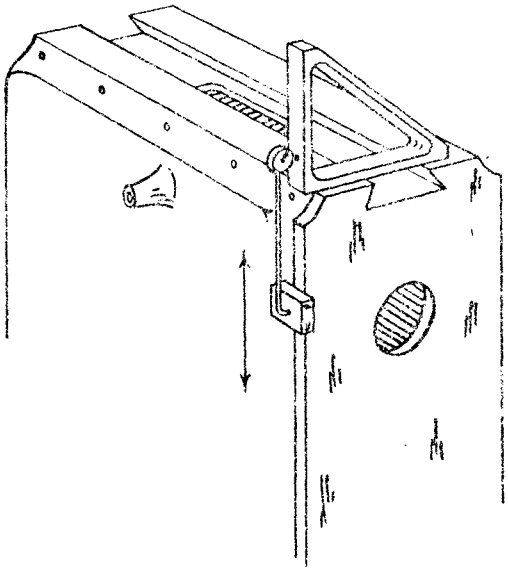

Fig. 27.42 Checking alignment of flat way of over arm to guiding way of column. Tolerance max. .001" in 18".

Sec. 27.38
OBJECTIVES: The Guiding Way of the Over Arm Support

1. To duplicate the original slope of the angular guiding way.
2. To be parallel to the axis of the spindle.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

There are two acceptable methods of dealing with OBJECTIVE NO. 1. First, if adequate hoisting equipment is available, it is feasible to utilize the mating surface i.e. the guided slide of the over arm member as a spotting template to help form the required angular slope on the guiding way of over arm support. Although the guided slide will be somewhat worn it will function well enough, provided alternate spottings are made with an ANGLE STRAIGHT EDGE to check straightness and indicate bearing quality.

The second method proposes to maintain the angle by means of the small DOVETAIL TEMPLATE shown in spotting position in Fig. 27.43. Supplementary spotting is executed with an ANGLE STRAIGHT EDGE. By the judicious alternate use of these tools, OBJECTIVE NO. 1 is realized.

The second method involving the construction of the TEMPLATE has much to recommend it. In the first place, the TEMPLATE helps preserve a definite slope on the guiding way. Second, in conjunction with a DIAL INDICATOR, it is used to test the alignment of this surface. Third, it is indispensable, as a pattern for making a TEMPLATE to produce an exact duplicate slope on the

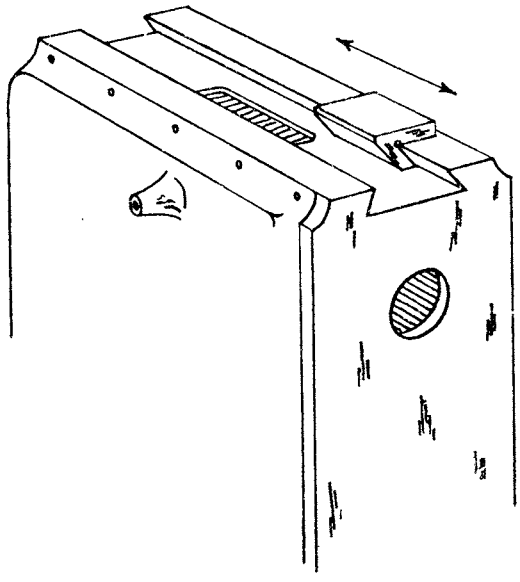

Fig. 27.43 Showing female dovetail template transferring marking compound to guiding way.

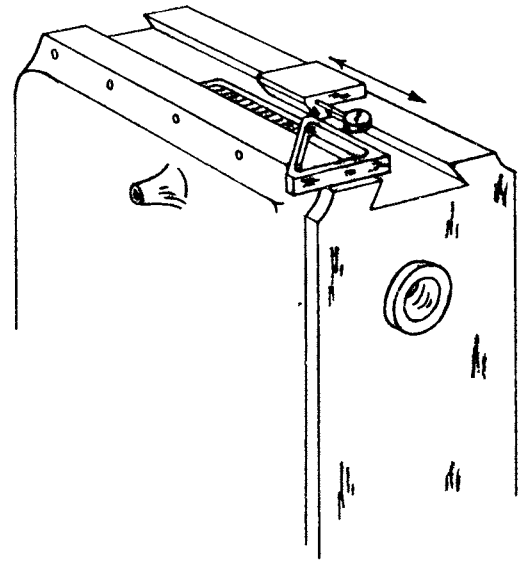

Fig. 27.44 General arrangement of tools for testing alignment of angular guiding way to axis of spindle. Maximum tolerance .001" in 18". Base of triangle must be parallel to face of column.

guided slide of the over arm member, which operation is discussed later.

There is only one alignment relating to this surface, for which an occasional test is made during the scraping operations. We may utilize the set up shown in Fig. 27.44, consisting of a DIAL INDICATOR fastened to an extension arm attached to the TEMPLATE. The operator moves the device along the guiding way, meanwhile riding the DIAL button against the SCRAPED TRIANGLE which is laid on the flat ways. (The base of the TRIANGLE is first aligned parallel with the face of the column.) This test checks the parallelism of the angular guiding way with the axis of the spindle, as required by OBJECTIVE NO. 2.

This arrangement is practical because the column face is already accurately aligned to the spindle axis. Thus the combination of the column face and the TRIANGLE provide a surface which is parallel to the axis of the spindle.

When the OBJECTIVES are completed, simultaneously, the guiding way is finished.

CAUTION: While applying the spotting tools, the groove should be examined for clearance.

Sec. 27.39

OBJECTIVES: The Gibbed Surface of the Over Arm Support

(A closely fitting straight flat gib is to be inserted.)

1. To match the slope of the angular guiding way of the over arm support.
2. To be parallel to the angular guiding way.
3. To have a surface quality of 4 - 5 bearing spots per square inch.

PROCEDURE:

A matching slope is produced on this angular surface by employing the same DOVETAIL TEMPLATE applied previously to the guiding way. To supplement the spotting and to indicate flatness an ANGLE STRAIGHT EDGE is utilized.

Attention is called to the fact that the bearing quality required on this surface is only 4 - 5 bearing spots per square inch. Though small, it is adequate because the gib to be inserted will have only stationary contact with this surface. Sliding bearing quality here would be superfluous.

The test for OBJECTIVE NO. 2 is repeated at intervals during the scraping in order to insure parallelism of this surface with the guiding way opposite. An

indicating jig of sufficient size to span the distance between the two surfaces is constructed for this check. A DIAL INDICATOR is attached, as represented in Fig. 27.45, and the apparatus is moved from end to end of the member meanwhile noting the reading.

When the three OBJECTIVES are satisfied, the gibbed surface is completed. This is the third and final surface of the over arm support on top of the column. Next we will scrape-in the over arm member itself.

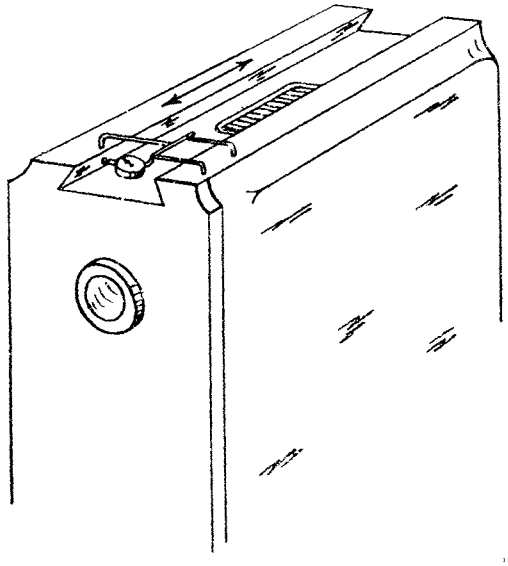

Fig. 27.45 Indicating jig and attached DIAL testing gibbed surface for parallelism with guiding way. Tolerance max. .001" in 12".

Sec. 27.40
The Practicality of a Female Dovetail Template

Whether or not the operator decides to take time to construct the Female DOVETAIL TEMPLATE, mentioned in Sec. 27.38, depends upon the way he sizes up his job. If the TEMPLATE is not made, it implies that the guiding way and the gibbed surface of the over arm support will be scraped to any chance slope that may evolve from the scraping process. It further means that when the surfaces of the over arm support are completed they must be utilized as a template to spot the over arm member itself. In no other way, if this procedure is adopted, can there be certainty of duplicating the slopes exactly enough to assure an area contact and a good fit between the slides and ways. If this system is followed, the over arm member must be lifted to the top of the column and inserted into the over arm support, then spotted. This must be repeated many times before the job is completed. Needless to say, such a method is difficult and time consuming but it will usually result in a superior fit.

A somewhat similar procedure was outlined in Sec. 27.38. In this section there was discussion of how the slope of the guiding way of the over arm support could be more closely controlled by using the more or less worn bearing surfaces of the over arm member as the spotting tool. Either of these methods will lead to proper fitting of the surfaces.

The alternative would be to construct a FEMALE DOVETAIL TEMPLATE and employ it in the manner previously described to produce identical slopes on the guiding way and the gibbed surface on the top of the column. Additionally, it can be used as a pattern to make a MALE DOVETAIL TEMPLATE capable of reproducing the selfsame slope on the dovetail surfaces of the over arm member. By adopting this procedure all spotting of the dovetail surfaces of the over arm member may be done conveniently and quickly at the work bench. Opposed to this saving of time and effort is the labor of producing the two TEMPLATES. Another drawback in producing templates is that extreme caution must be exercised to duplicate precisely the slope of the pattern. Errors however slight, cannot be tolerated because they will be reproduced in the bearing surfaces. This point is amplified in Sec. 12.16.

Thus weighing the advantages against the disadvantages, no hard and fast rule can be laid down in regards to the practicality of the TEMPLATES. It is a matter of choice for the individual operator. When the surfaces in question are only slightly worn, the operator may work efficiently without the TEMPLATES. But if the bearing surfaces are moderately to heavily worn, we recommend that the TEMPLATES be constructed.

Sec. 27.41
The Over Arm Member

This is a rigid casting, adjustable along its axis, which carries the outer arbor bearing support. The over arm member slides on the bearing surfaces of the over arm support. The construction described here is the conventional type of male dovetail consisting of two flat slides and two angular slides. Identification of the surfaces is made by reference to the accompanying diagram, Fig. 27.46.

PLATE 44. Column of horizontal milling machine. Overarm is retracted. Mounted knee features dovetail form of bearing surfaces. (Courtesy - Cincinnati Milling Machine Co.)

The logical order of scraping the bearing surfaces of the over arm is as follows:

1. The flat slides.
2. The angular guided slide.
3. The angular gib slide.

Sec. 27.42
OBJECTIVES: The Flat Slides of the Over Arm Member

1. To be parallel to each other.
2. To be fitted to the flat ways of the over arm support with a surface quality of 10 - 15 bearing spots per square inch.

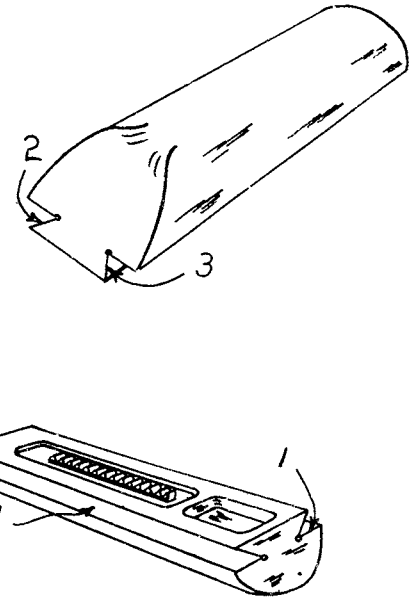

Fig. 27.46 The Over Arm Member of horizontal milling machine.

(1) flat slides (2) guided slide (3) gib slide

PROCEDURE:

Reference to Fig. 27.46 reveals immediately that the design of the member precludes the use of a standard SURFACE PLATE to spot the flat slides. The simplest method to get around this difficulty is to spread marking compound on the scraped flat ways of the over arm support (on top of the column) and then slide the over arm member into place on them. Thus the flat slides of the over arm member are spotted as the compound is transferred.

Tests to detect "wind" should be made frequently because these surfaces are very susceptible to this tendency. To reduce the probability of this occurrence, and insure flatness, it is a good practice to spot alternately with an ANGLE STRAIGHT EDGE.

A lack of hoisting equipment, or a shortage of shop help, may necessitate the use of other procedures in dealing with these surfaces. Alternative plans of handling problems of a similar nature are discussed in Chapter 25.

The alignments required of the flat slides by OBJECTIVE NO. 1 may be tested with the set ups described in detail in the Chapter mentioned above.

The bearing quality should be worked in at the same time the alignment is secured. When a final spotting with the mateing member reveals uniform distribution and coloration of markings, a good fit is indicated as per OBJECTIVE NO. 2.

Sec. 27.43
OBJECTIVE: The Guided Slide of the Over Arm Member

1. To be fitted to the guiding way of the over arm support with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

In treating the guided slide of the over arm member, advantage can be taken of the fact that this heavy casting must be hoisted to the top of the column when the flat slides are fitted to the flat ways of the over arm support. Anticipating this operation which must be repeated a number of times, the experienced scraper will utilize the guiding way of the over arm support as a spotting template for the surface in question. Thus while fitting the flat slides to the flat ways, much progress can be made in fitting the guided slide to the guiding way.

As an alternative measure he can construct a MALE DOVETAIL TEMPLATE to supplement the spotting operation. This gage can be produced by using as a pattern, the FEMALE DOVETAIL TEMPLATE, made previously for the guiding way of over arm support. In this way the TEMPLATE will help generate a duplicate slope on the guided slide of the over arm member. Such a TEMPLATE simplifies the spotting operation as much of the job can now be performed at a work bench.

The ANGLE STRAIGHT EDGE should be applied alternately to help keep the surface flat and indicate the bearing quality.

OBJECTIVE NO. 1 is deemed accomplished when the guided slide shows area contact with its mateing way and adequate bearing quality. These characteristics are determined routinely at a final inspection of the bearing surface after traversing the sliding member the maximum distance.

Sec. 27.44
OBJECTIVES: The Gib Slide of the Over Arm Member

1. To match the slope of the gibbed surface of the over arm support.
2. To be parallel to the guided slide of the over arm member.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

After the flat slides and guided slide are scrape-finished, the gib slide of this member can be spotted on the gibbed surface of the over arm support. Handling the job would be similar to the method of treating the surface just discussed.

The DOVETAIL TEMPLATE which was mentioned as an alternative method in the previous section can also be applied effectively to this surface.

Both of these spotting operations should be supplemented with an occasional application of the ANGLE STRAIGHT EDGE to achieve OBJECTIVE NO. 1.

The reason for the emphasis on matching the slope of the gibbed surface is that it is necessary to have two parallel surfaces since a closely fitting flat gib piece is to be used. (Ordinarily, this gib piece is sized on a surface grinder and not hand scraped.)

To satisfy OBJECTIVE NO. 2, a test for parallelism can be conducted using any of the several techniques described for similar situations. (See Fig. 25.15 showing use of vernier calipers and cylinders and Fig. 25.14 illustrating application of DIAL INDICATOR and jig.)

All three OBJECTIVES of the gib slide must be attained simultaneously, thereby finishing the over arm member, except for a final test.

Conducting a Sliding Member Test on the Over Arm Member

After the over arm member is completed, it is installed, or inserted, into position and the flat gib is slid in place. The gib is adjusted for sliding tension. Then to determine the smoothness of operation, the over arm is moved in and out on its bearing surfaces by turning the

pilot wheel, shown in Fig. 27.1. The absence of looseness, or binding, is the final proof that the bearing surfaces of the over arm member are parallel.

Sec. 27.45
OBJECTIVES: The Outer Bearing Arbor Support

1. Bore to be aligned in the horizontal and vertical planes with the axis of spindle.
2. Bearing surfaces to be fitted to the slides and ways of the over arm member with a quality equivalent to 10 - 15 bearing spots per square inch.

PROCEDURE:

To provide support to the arbor at its free end, an outer bearing is standard equipment for this type of machine. It is illustrated in Fig. 27.47.

In scraping the bearing surfaces of both the over arm support and the over

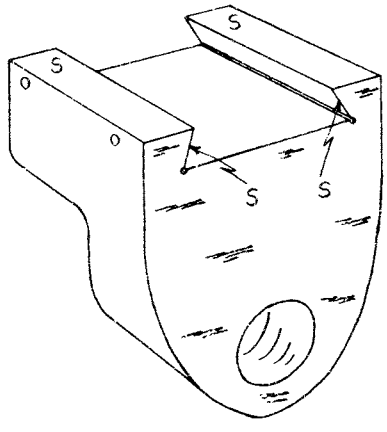

Fig. 27.47 The outer bearing arbor support horizontal milling machine.

(s) surfaces to be scraped and fitted to over arm member.

arm member, we have unavoidably misaligned the arbor support hole, or bore, of the outer bearing support. Consequently, this member must now be scraped to correctly align the hole with the axis of the spindle as directed by OBJECTIVE NO. 1.

The four surfaces, lettered (s) in Fig. 27.47, must be scraped and fitted to the over arm member. Since the procedure is comparable to that discussed in treating the ways of the over arm support, the reader is referred to the appropriate section. Fig. 27.48 shows the set up for the alignment test of the bore and demonstrates the swing round application of the DIAL INDICATOR. Other procedures, such as the double test bar method or the slip bushing method, referred to in Sec. 16.5 and Sec. 16.7 respectively, are also applicable.

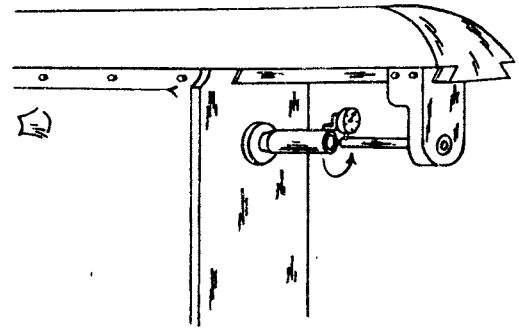

Fig. 27.48 Method of checking alignment of outer bearing arbor support to spindle by means of a swing-round test. Tolerance max. for run out .001" at 12".

An alternative means of positioning the bore of the arbor support would be to disregard alignments altogether while scraping the bearing surfaces of this member to an overall fit with the bearing surfaces of the over arm member. Then with the outer bearing arbor support clamped in position to the over arm, the hole is precision bored. A boring bar held in the spindle will produce an accurately aligned hole which then can be bushed. The component is fed to the cutting tool by turning the pilot wheel which moves the over arm member.

With this alternative procedure the OBJECTIVES are accomplished consecutively not simultaneously.

Incidentally, should a horizontal milling machine be equipped for additional support with an intermediate arbor support bearing, it would be handled in a manner similar to the above.

This completes all the members associated with the over arm construction and we turn now to the next member, the saddle.

Sec. 27.46
The Plain Saddle

The saddle member is supported on

the knee and is guided transversely by the ways of knee. Fig. 27.49 shows the Lower Bearing Surfaces of the plain saddle which are associated with the knee member. Fig. 27.50 illustrates the Upper Bearing Surfaces of the saddle, which are in contact with, and guide the table.

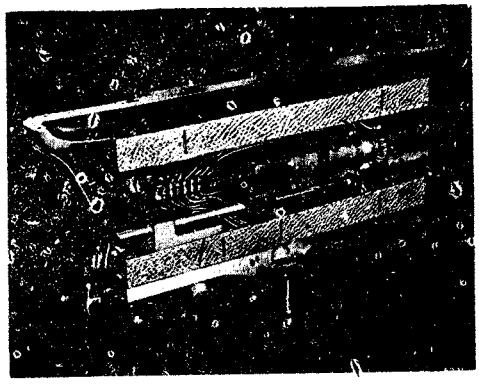

PLATE 45. View of top surfaces of saddle of horizontal milling machine. Notice oil grooves spaced along finely scraped ways. (Courtesy - Cincinnati Milling Machine Co.)

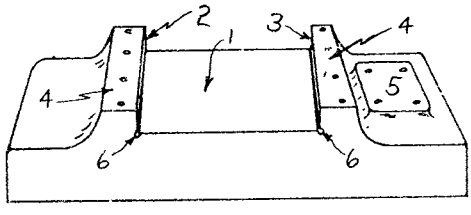

Fig. 27.49 The lower bearing surfaces of saddle of horizontal milling machine.

(1) flat slide (2) guided slide (3) lower gibbed surface (4) gib bracket bearings (5) saddle nut boss (6) groove.

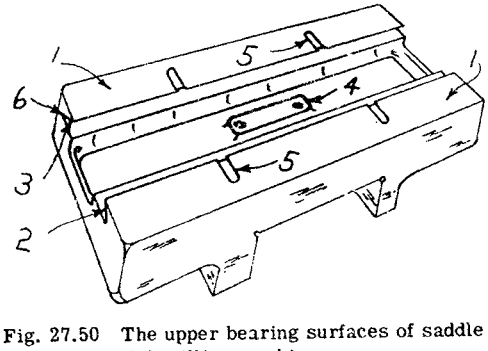

Fig. 27.50 The upper bearing surfaces of saddle of horizontal milling machine.

(1) flat ways (2) guiding way (3) upper gibbed surface (4) table nut boss (5) receptacle for felt oil pads (6) groove.

The identification of the groups of surfaces to be scraped and the preferred sequence is enumerated as follows:

The Upper Bearing Surfaces:
- The flat ways
- The guiding way
- The upper gibbed surface

The Lower Bearing Surfaces
- The flat slide
- The guided slide
- The lower gibbed surface
- The gib bracket bearings.

Sec. 27.47
Exploratory Examination

In commencing work on the saddle, the operator is handicapped because there is no finished surface or reliable check point on the member itself, to use as a basis for alignments. Consequently, he must proceed in very much the same manner as he was obliged to do with the knee member. (A review of Sec. 27.15 will be helpful.) In short, an Exploratory Examination is called for with both lower and upper surfaces inspected for wear. When this is done and all possible information gathered, the flat slides and the guided slide of the lower surfaces and the flat ways and the guiding way of the upper surfaces are dealt with on the basis of the accumulated facts. Several scraping cycles are usually performed on each surface to obtain a reasonably flat bearing surface and thereby improve the reliability of the alignment tests that follow.

Sec. 27.48
Determining Misalignment

Three alignment tests are made to obtain information relative to the amount of misalignment present on the member. After placing the saddle on the knee, the tests are conducted using the set ups shown in Fig. 27.51, Fig. 27.52, and Fig. 27.53.

When the tests are completed the total error will be known. Dividing this error, pro-rata between the upper and lower groups of bearing surfaces is the next step. The division is made on the basis of our analysis of the amount of

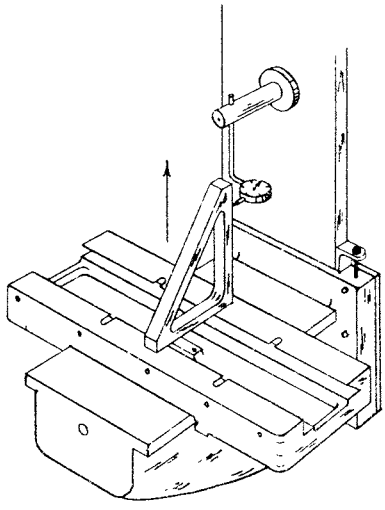

Fig. 27.51 Aligning flat ways of saddle to face of column. Maximum tolerance .001" in 18". Preferably low at rear. (Compare with Fig. 27.36(a) and Fig. 27.36(b).)

wear shown by the individual bearing. The more accurately this is done, the more closely the scrape-finished surface will parallel the plane of the original factory surface.

Since the routine of accomplishing this was described in detail when introducing the knee member, it would be repetitious to cover the same ground. Rereading those passages which are pertinent to the present circumstances, particularly Sec. 27.16 and Sec. 27.21 should be helpful. When the proportion of the total error to

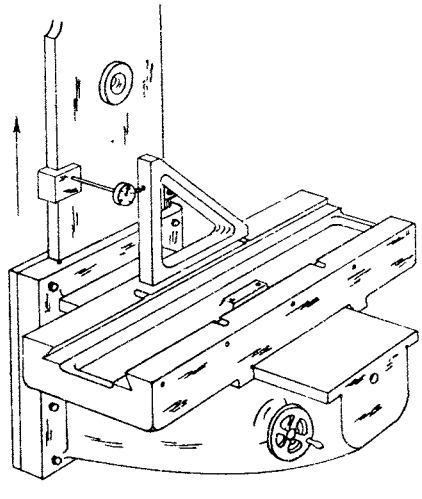

Fig. 27.52 View showing method of testing alignment of flat ways of saddle to guiding way of column. Maximum tolerance .001" in 18". (Compare with Fig. 27.37(a) and Fig. 27.37(b).)

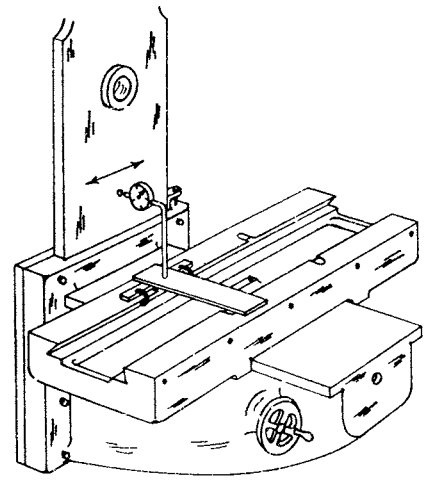

Fig. 27.53(a) Method of testing alignment of guiding way of saddle to face of column.

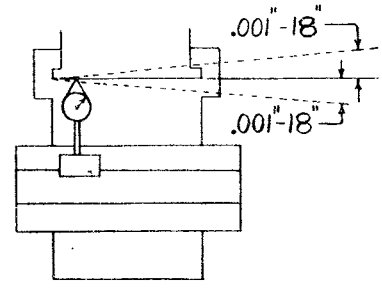

Fig. 27.53(b) Guiding way of saddle to be parallel to column face. Plus and minus tolerance indicated.

be corrected on each group of surfaces is decided, the actual scraping of the individual surfaces can begin.

Sec. 27.49
OBJECTIVES: The Flat Ways of the Saddle

1. To be parallel to each other
2. To satisfy, in part, the requirement that the flat ways be square with the column face.
3. To satisfy, in part, the requirement that the flat ways be square with the guiding way of the column.
4. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

An inspection of the flat ways of the saddle will usually reveal that the ends

are more heavily worn than the middle portion due to the overhang of the table. The convexity is in fact well defined in most cases. Consequently, it might be advisable at this point to suggest that after the OBJECTIVES given above are effected, it is good practice to provide the extremities with a denser surface bearing quality than the mid area to equalize the rate of wear between them. In brief, the formation of a compound bearing may sometimes be desirable to improve the durability of the ways. This is explained in some detail in Sec. 19.10 and Sec. 19.11.

Spotting the flat ways of the saddle is alternated between a SURFACE PLATE and a STRAIGHT EDGE. OBJECTIVES NO. 1 and NO. 4 are satisfied when the markings are uniform in coloration and distribution. To prevent the development of a convex surface, the "Spin" test should be applied at frequent intervals. Examinations for "wind" are also made.

From time to time, the tests illustrated in Fig. 27.51 and Fig. 27.52 need to be repeated. They will disclose proximity to the goal sought in OBJECTIVES NO. 2 and NO. 3. Partial alignment of the saddle has now been effected. The balance of the misalignment will be eliminated when treatment of the saddle flat slide begins.

Sec. 27.50
OBJECTIVES: The Guiding Way of the Saddle

1. To duplicate the original slope of the angular way.
2. To satisfy, in part, the requirement that the guiding way of the saddle be parallel with the column face.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The first step in treating this surface is the determination of the slope of the angular guiding way. In brief, the necessary information is obtained by inspecting the least worn portion of both the guiding way of the saddle and its mateing surface, the guided slide of the table. Obviously, this information would have to be secured from the guiding way prior to the time of making the Exploratory Examination, as subsequent removal of metal would destroy the existing angular value.

After a decision is made as to the angle, the operator should either make up a small DOVETAIL TEMPLATE, or use a bevel protractor to preserve this slope during the process of scraping. The advantage of constructing a DOVETAIL TEMPLATE is that it can be also used to spot the upper gibbed surface of the saddle, the next bearing to be scraped.

An alternative procedure would be to use the guided slide of the table as a spotting tool. Even though this bearing surface will undoubtedly be worn, it will nonetheless spot with sufficient accuracy so that its angular value may be duplicated on the slope of the guiding slide of the saddle.

The ANGLE STRAIGHT EDGE is alternately employed to preserve flatness and indicate the bearing quality of the surface. After inserting the tool for this purpose, it is necessary to inspect the groove for clearance to prevent bottoming the tool.

When the work is fairly well advanced and flatness is indicated, it is advisable to learn how closely the surface comes to meeting the conditions of OBJECTIVE NO. 2. Conducting the alignment test illustrated in Fig. 27.53a will provide the necessary guidance. Remember, though, that only a predetermined fraction of the total original error is being cancelled by scraping this surface. (Fig. 27.53b) The balance of the misalignment will be corrected later by scraping the guided slide of the saddle.

The actual physical set up for conducting the test is shown in Fig. 27.53a. It includes an indicating jig, consisting of two pieces of flat stock fastened together at 90°. At both ends of the cross piece, short lengths of rod are attached and curved downward against the guiding way. A DIAL INDICATOR is then attached to the jig as shown.

With the guided slide pushed firmly against the guiding way of the knee, the contact point of the DIAL is set against the column face. While the legs of the indicating jig are kept in touch with the guiding way of the saddle, the device is moved from end to end of the saddle ways.

A reading is taken at both sides of the column face.

NOTE: If wear has been normal on this surface it will be denoted by a convex condition consisting of a lightly worn middle area and heavily deteriorated ends. Such a condition suggests that a compound bearing will be suitable for this surface.

Sec. 27.51
OBJECTIVES: The Upper Gibbed Surface of the Saddle

(A straight flat gib is to be fitted for the table.)

1. To be parallel with the guiding way.
2. To have a surface quality of 4 - 5 bearing spots per square inch.

PROCEDURE:

The treatment of the upper gibbed surface of the saddle member depends to a considerable extent upon the gib piece that is to be inserted. A decision must be made at this point whether it shall be a closely fitting, or a loosely fitting, flat gib. Usually the decision will be influenced by the treatment accorded the surface at the time of manufacture. If this surface was hand scraped when manufactured, similar renovation is advisable when reconditioning the machine. A close fitting gib will then be appropriate. On the other hand, if finish machining was the final operation at the factory, hand scraping seemingly would be superfluous at this stage. As a result a loose fitting straight flat gib will be the logical selection.

In this discussion, we will assume a close fitting flat gib is favored. Should that be the choice, the gibbed surface of the saddle must be carefully prepared for it. Inspection of the gibbed surface for signs of warping is the first operation. Then alternating between an ANGLE STRAIGHT EDGE and the DOVETAIL TEMPLATE, the surface is spotted. This TEMPLATE, though prepared for the guiding way, can be used profitably here as well.

A second template will subsequently be made from this one. The purpose of the second template, will be to duplicate the slope of the upper gibbed surface of the saddle on the gib way of the table member. These two surfaces must have identical slopes if a tight fitting flat gib is to be accommodated. Discussion of this matter is reserved for a later paragraph.

To assure parallelism with the guiding way, as required by OBJECTIVE NO. 1, a suitable indicating jig is made up. A DIAL is attached, and readings are taken in the customary manner. Scraping is not concluded until both OBJECTIVES are fulfilled.

The operator will find that on some machines, the upper gibbed surface of the saddle has not been scraped after being machined. In these cases the operator may conform to the original manufacturing plan and leave the gibbed surface untouched, unless excessive warping has occurred. When this plan is followed, the old gib piece can be used again. This presumes a loose fitting gib arrangement and consequently OBJECTIVES NO. 1 and NO. 2 do not apply.

This completes all the Upper surfaces of the saddle. Next we will turn our attention to the lower surfaces of the saddle.

Sec. 27.52
OBJECTIVES: The Flat Slide of the Saddle

1. To be parallel with the flat ways of the saddle.
2. To be fitted to the flat ways of the knee with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The flat slide of the saddle member shown in Fig. 27.49 is spotted most efficiently by rubbing it on the flat way of the knee. The latter named surface, having been coated with marking compound, serves as a spotting template. Fig. 27.54 shows the two members in position. Before separating them the groove is checked to make certain it provides ample clearance. An adequate groove is necessary so that the entire flat slide of the saddle may be scraped flush to the guided slide, thereby preventing the formation of a fillet. (Refer to Sec. 18.5 for additional data on this point.)

The check for OBJECTIVE NO. 1 is

PLATE 46. Showing assembler testing alignment of the flat way of saddle square with guiding way of column. Note the SCRAPED PARALLEL and TRIANGLE. In the set up pictured, the knee and saddle members remain stationary and the DIAL INDICATOR attached to a gage is moved up and down on the guiding way. (Courtesy - Cincinnati Milling Machine Co.)

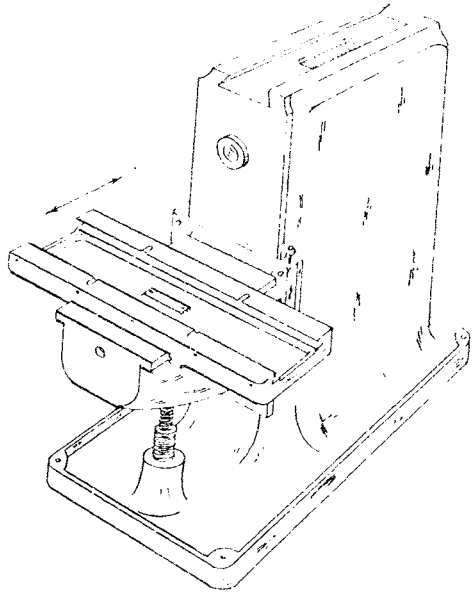

Fig. 27.54 Method of spotting the flat slide of saddle on the coated surface of flat way of knee. Rubbing movement is in direction of arrow.

executed with the set up as illustrated in Fig. 27.55. The flat slide of the saddle is placed on PARALLELS set on a SURFACE PLATE. A DIAL INDICATOR attached to a Surface Gage is brought into contact with the saddle flat ways at four points, viz: (a), (b), (c), and (d). If the readings are identical at all four locations, the flat slide and flat ways of the saddle are parallel, satisfying OBJECTIVE NO. 1. Any variation must be corrected by scraping the saddle flat slide, not the saddle flat ways which have been completed.

As an alternate check, it may be well to conduct the alignment tests on the saddle as illustrated in Fig. 27.51 and Fig. 27.52. The reading thus obtained will be identical with those secured in the tests pictured in Fig. 27.36a and Fig. 27.37a provided the flat slide of the saddle is parallel with the flat ways of the saddle. Any misalignment discovered, can be rectified in the manner described in the paragraph immediately above.

By fulfilling OBJECTIVE NO. 1 exactly, the misalignment which was partially reduced by scraping the flat ways of the saddle is now totally eliminated.

While scraping this surface parallel, we should also be producing the required bearing quality. With both OBJECTIVES satisfied, the flat slide of the saddle is completed.

CAUTION: To prevent scratches, all grit must be removed from this saddle surface before placing it in contact with the scrape-finished flat way of the knee member.

Sec. 27.53
OBJECTIVES: The Guided Slide of the Saddle

1. Guiding way of the saddle to be parallel with the column face.
2. To be fitted to the guiding way of the knee with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The first step in treating this surface is to ascertain the degree of misalignment still present. To this end the test shown in Fig. 27.53a is conducted. The results of this test will determine the

degree and direction of the remaining error.

Steps towards the realization of the OBJECTIVES is begun by coating the guiding way of the knee with marking compound and lightly oiling the flat way of the knee to provide lubrication for the flat slide of the saddle when that member is laid on top.

Care should be exercised in placing the two members together. The saddle is set on the knee and the guided slide of the saddle is pushed firmly against the guiding way of the knee. This done the groove should immediately be checked for clearance. Then holding the saddle in the manner just described, it is moved back and forth to transfer the compound. Alternate applications of a RIGHT ANGLE TEMPLATE (See Fig. 27.56) and

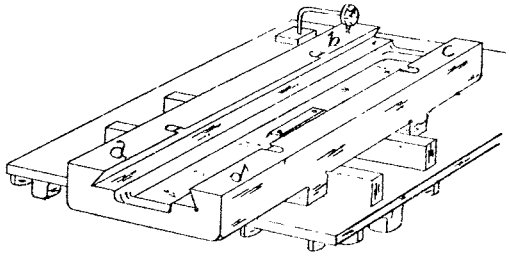

Fig. 27.55 Checking parallelism of flat slides to flat ways of saddle.

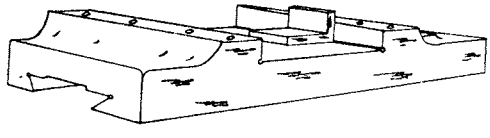

Fig. 27.56 Spotting guided slide of saddle with a right angle template.

of a STRAIGHT EDGE will diminish the frequency that the saddle must be placed on the knee for spotting purposes.

Scraping is conducted in accordance with the transferred markings. During the course of this work, we should repeat the Alignment Test for OBJECTIVE NO. 1. Fig. 27.53b shows the tolerance allowed for the guiding way of the saddle. This tolerance is not to be exceeded. Any error still present is gradually eliminated by resuming scraping on the guided slide of the saddle.

For an arrangement affording greater accuracy than that illustrated in Fig. 27.53a, a long scraped PARALLEL can be positioned against the column face. Now the contact point of the DIAL will ride against the scraped PARALLEL instead of the column face. The advantage of this arrangement is that it permits the indicating jig to make the maximum travel across the saddle. Readings are taken at both ends. If each reading is the same, or within the allowed tolerance, the alignment is satisfactory.

The desired bearing quality (OBJECTIVE NO. 2) should be developed simultaneously.

NOTE: It is considered sound practice to work on the guided slide of the saddle at the same time as the flat slide of the saddle, thereby reducing the number of times this member needs to be placed on the knee for spotting purposes. In other words, both of these surfaces can be spotted in one operation.

Sec. 27.54
OBJECTIVES: The Lower Tapered Gibbed Surface of Saddle

1. To be square with the flat slide of the saddle.
2. To have a surface quality of 4 - 5 bearing spots per square inch.

PROCEDURE:

Treatment of this surface will be pointed toward making it suitable for the insertion of a tapered gib piece. Whether or not the same taper is produced on this surface while attaining the OBJECTIVES is immaterial, unless the original tapered gib is to be reused. In that case it must be duplicated.

The spotting and scraping processes on this surface are conventional. Consequently, by alternating the application of a STRAIGHT EDGE and a RIGHT ANGLE SPOTTING TEMPLATE, flatness can be generated, and a 90° alignment with the flat slide maintained. In addition to using the TEMPLATE to help obtain OBJECTIVE NO. 1, the operator may use the knee member as a spotting

tool. To this end the gib way of the knee is coated with compound and the gibbed surface of the saddle is spotted on it.

Sometimes an obstruction, such as a boss on the casting, prevents swiveling the saddle and moving it over to accomplish this, but when feasible it is considered good spotting practice to do so. The reason that the method is advantageous is that if area contact is achieved, it denotes parallelism between gib way of knee and the gibbed surface of saddle and this condition, in turn, will facilitate the fitting of the tapered gib since all transverse taper will have been eliminated.

Since the bearing quality demanded is not high, no difficulty should be experienced in speedily completing the two OBJECTIVES.

Sec. 27.55
OBJECTIVES: The Gib Bracket Bearings of the Saddle

1. Height of the gib bracket bearing surfaces, measured from the saddle flat slide to be equal to the thickness between the knee flat way and the knee gib bracket ways, plus an allowance for oil film.
2. To be parallel with the flat slide of the saddle.
3. To have a surface quality of 4 - 5 bearing spots per square inch.

PROCEDURE:

The gib bracket bearings shown in Fig. 27.49 are not sliding bearing surfaces but nonetheless may require considerable removal of metal. This would be occasioned if heavy scraping on the knee flat way and knee gib bracket ways was required to attain a scrape-finished surface. Thus the principal difficulty encountered in treating these surfaces is in fulfilling OBJECTIVE NO. 1.

To assist in testing for OBJECTIVES NO. 1 and NO. 2, a depth micrometer is used. The procedure is the same as explained under Sec. 27.29 (Gib Bracket Bearings of the Knee.)

The reason for adding an extra .0005" to .001" to the height dimension is to provide clearance between the slides of saddle and ways of knee. This additional height will provide space for the oil film. Too much clearance in this vertical direction should not be allowed because excessive looseness of the saddle may result in chatter from the pressure of a heavy, intermittent cut on the work piece when the machine is finally placed in use.

Either a SURFACE PLATE or a STRAIGHT EDGE may be used to apply marking medium to these surfaces.

Operations should be synchronized so as to complete all OBJECTIVES at one time.

Sec. 27.56
OBJECTIVES: The Saddle Nut Boss

1. To be parallel with the flat slide of the saddle.
2. To have a surface quality of 2 - 3 bearing spots per square inch.

PROCEDURE:

The saddle nut boss shown in Fig. 27.49 must be scraped parallel with the flat slide. This is required so that when the nut is bolted to the boss, the threaded bore of the nut will be parallel to the line of travel of the saddle. Otherwise the feed screw will bind.

OBJECTIVE NO. 1 may be tested with a DIAL INDICATOR affixed to a Surface Gage by measuring from the flat slide.

No problem is involved in fulfilling OBJECTIVE NO. 2.

NOTE: The saddle nut is shown in the accompanying Fig. 27.57 bolted to the saddle nut boss. This type of construction is found on some machines. The side of the knee is cored out to permit

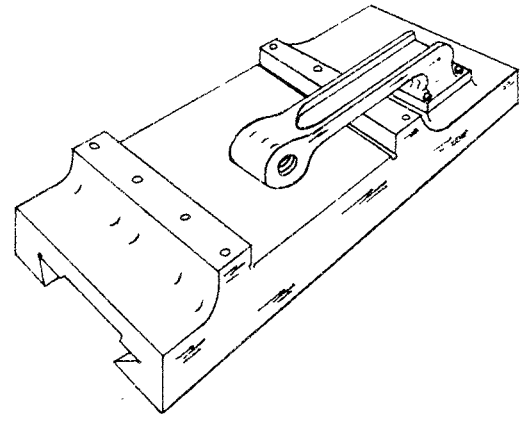

Fig. 27.57 Saddle nut attached to saddle nut boss.

the entry of the saddle nut inside the knee casting.

Sec. 27.57
The Gib Brackets of the Saddle

The saddle gib brackets are rectangular castings, scraped on one side. They bolt to the saddle gib bracket bearings and their function is to hold the saddle flat slide in contact with the flat way of the knee. They have sliding bearing against the knee gib bracket ways. Fig. 27.58 represents one of the brackets in simplified form.

OBJECTIVES: The Gib Brackets of the Saddle

1. To be flat (one side only)
2. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:
These brackets are spotted most easily on a SURFACE PLATE. Scraping is not terminated until the two OBJECTIVES are attained. The proof of this is in a uniform coloration of the markings and an even distribution thereof. For additional data, refer to Sec. 27.30 (Gib Brackets of Knee.)

Sec. 27.58
OBJECTIVES: The Tapered Gib of the Saddle

1. To be fitted to the knee gib way with a surface quality of 10 - 15 bearing spots per square inch.
2. To be fitted to the saddle gibbed surface with a surface quality of 4 - 5 bearing spots per square inch.

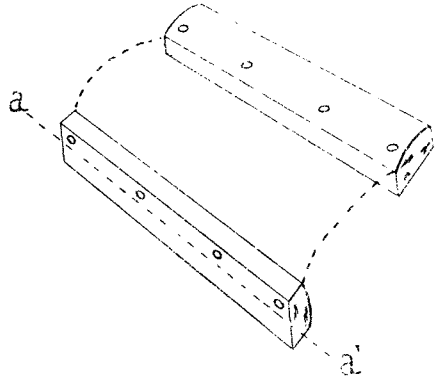

Fig. 27.58 Gib brackets of saddle. One side is scraped. The portion above line (a-a') bolts to the gib bracket bearings of saddle; that part below the line (a-a') has sliding bearing on the gib bracket ways of the knee.

PROCEDURE:
Since the problems involved in preparing a tapered gib have been touched on in other parts of the book, principally Sec. 17.17 through Sec. 17.22, it is suggested that these portions be reread in preparation for the following:

After the operations have been carried to this stage, the saddle is placed on the knee and the tapered gib is fitted. Fitting is not a job which can be disposed of without supplementary checking. For instance, it is advisable to stop just short of completion so that certain tests may be conducted on the ways of the knee to determine if they are parallel. These are the Sliding Member Tests which follow. If they indicate that parallelism is achieved on the knee ways, then the tapered gib piece may safely be finished.

Sec. 27.59
Testing Parallelism of the Ways of the Knee

PROCEDURE:
Before passing the knee member as acceptable, good scraping practice suggests a FINAL CHECK for PARALLELISM of the ways of the knee. This undertaking enables the operator to certify that the knee is finished accurately. Preliminary measurements with the DIAL INDICATOR, or other gages or tools, may have been inaccurate or the operator may have erred in orienting the results of his check. Thus to eliminate all possibility that these surfaces of the knee are out of true, this final check should be made. The tests involve the relationship of the following surfaces, viz:

1. The gib way to the guiding way of the knee.
2. The gib bracket ways to the flat way of the knee.

Preparation for the tests consists of cleaning and freshly oiling the ways of the knee and the slides of the saddle.

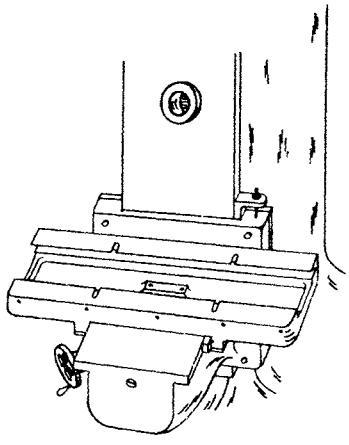

Fig. 27.59 Horizontal milling machine prepared for application of sliding member test on knee ways.

After assembling the members and placing them together, the saddle gib is inserted and adjusted for sliding tension, as represented in Fig. 27.59. This condition can be determined as the saddle is slid back and forth by hand and tested for bind or looseness.

If either a tight or slack condition is detected, either the gib way or the gib bracket ways of the knee, represented in Fig. 27.27 are out of true and must be rescraped to rectify this error. We cannot make the correction on the knee flat way or guiding way because they are already scrape-finished and aligned. Therefore, any indication of nonparallelism must be eliminated by treating the other two surfaces mentioned. Sometimes only one surface is at fault. It is suggested that the procedure outlined in Sec. 27.32 be adopted.

At the conclusion of the test for parallelism, a few miscellaneous, though important, operations are now performed, namely:

1. When all surfaces of the knee are parallel, within the tolerance allowed, the tapered gib piece of the saddle is given its final bearing quality.
2. The saddle is removed from the knee as it will now be used as a template to spot the slides of the table.
3. This is the opportune time to frost the ways of the knee member if decoration is desired.

Sec. 27.60
The Universal Saddle

Many horizontal milling machines are equipped with a universal or swivel saddle. Since this feature is so common, it would be advisable to discuss the advantages of this member, to explain the methods of treating the various bearing surfaces, and to describe the required alignment tests.

The universal saddle shown in Fig. 27.60a consists of two components, namely:

1. The swivel block (lower section) which is fitted to the ways of the knee which guide it in transverse movement.

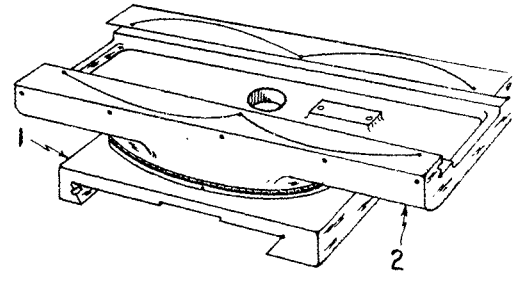

Fig. 27.60(a) Diagram of Universal Saddle of horizontal milling machine.

(1) Swivel block, or lower section (2) The saddle, or upper section

2. The saddle (upper section) which is fitted to the swivel block (lower section) and supports and guides the table in longitudinal movement.

In addition to longitudinal and transverse movements, the universal saddle can be swiveled angularly in the horizontal plane about a pivot connecting the saddle to the swivel block.

This sectional construction provides the table member with an extra facility. In addition to the usual movements in the transverse, longitudinal, and vertical directions, it can be swung horizontally through 45° each side of center and can be clamped at any point. This swivel movement makes possible helical milling.

Although this universal feature adds to the utility of a horizontal miller so equipped, it makes the job of rescraping the member that much more complicated

Without being technical, the two sections of the universal saddle are centrally connected by a ring or pivot. The upper section swivels horizontally about the axis of the pivot.

Two special problems induced by the presence of the pivot axis are involved in treating this member. First, as a result of wear on several bearing surfaces of various members, the axis of the pivot gradually becomes displaced with reference to its original alignment with the axis of the spindle. This displacement occurs in the longitudinal direction.

Secondly, as a consequence of normal wear on other surfaces of other members, the center T-slot of the table becomes displaced with respect to its original alignment with the axis of the pivot. This misalignment takes places in the transverse direction.

As these several surfaces are reconditioned, the removal of metal to effect various OBJECTIVES, including an adequate bearing surface, further increases the amount of offset for these two alignments. This also is unavoidable. These problems will be discussed in their proper place.

After this digression, we return to a further consideration of the two sections of the universal saddle. Fig. 27.60b illustrates the Horizontal Milling Machine to which the universal saddle will be attached. Since the column and knee members shown are assumed to be scrape-finished, the work continues with the fitting and alignment of the universal saddle. In passing, it will be noted that both the column and the knee feature the dovetail bearing construction.

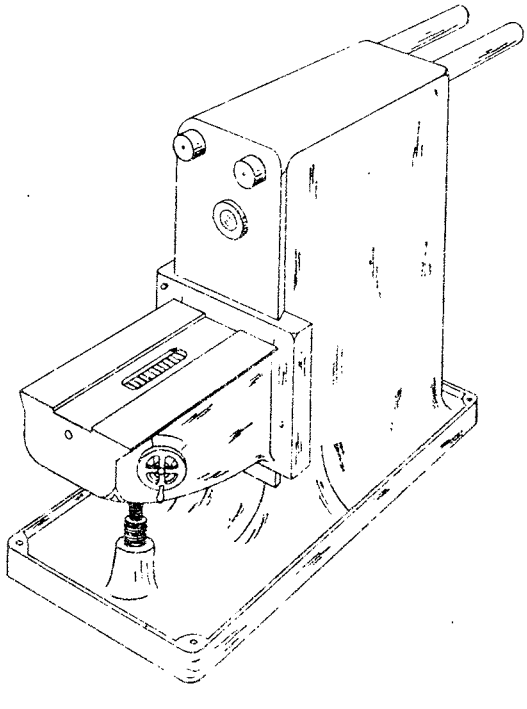

Fig. 27.60(b) Horizontal milling machine featuring dovetail bearing surfaces on column and knee.

Sec. 27.61
The Swivel Block

(The lower section of the Universal Saddle.)

The lower section, or swivel block, comprises four bearing surfaces, enumerated as follows, viz:

1. Flat slides
2. Angular guided slide
3. Angular gibbed surface
4. Circular way.

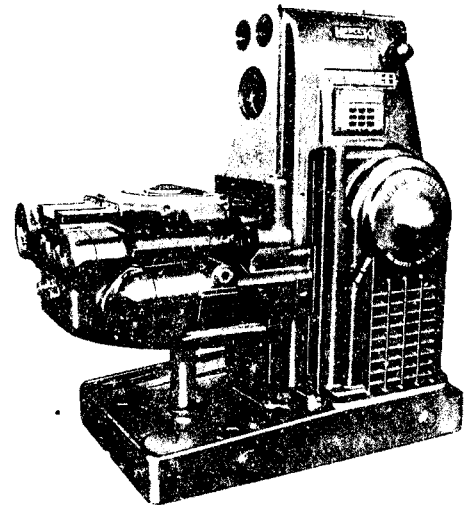

PLATE 47. Column unit mounting knee and swivel block of horizontal milling machine. (Courtesy - Kearney & Trecker Corp.)

These surfaces are easily identified by reference to Fig. 27.61.

In undertaking to scrape these bearing surfaces the operator is under no compulsion to scrape the flat slides and the

circular way in the sequence numbered above. Ordinarily, the order to be selected depends on the state of deterioration. Good practice favors starting with the surface having the best condition.

In our imaginary case we will assume that the ways of the knee were in fairly good condition. Logically, it follows then that the mateing surfaces of the

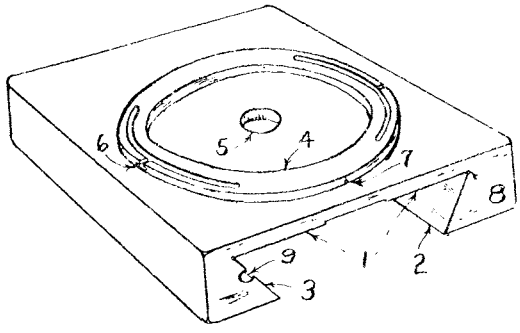

Fig. 27.61 View showing swivel block and principal bearing surfaces and other features.

(1) flat slides (2) angular guided slide (3) angular gibbed surface (4) circular way (5) pivot hole (6) circular T-slot for clamping bolt (7) graduation marker (8) groove (9) gib adjustment screw slot

swivel block would probably also be in good condition. This means that the bearing surfaces listed above as #1, #2, and #3 consisting of the flat slides, the angular guided slide, and the angular gibbed surface, respectively, should be scraped in that order. Finishing with the circular way, #4, completes the job.

On the other hand, if the circular way was in a superior condition and there were no compensating factors, it could be done first, followed by the other surfaces as listed immediately above.

Another point to consider is that if the circular way were cast in a chill at the time of manufacture, it would be too hard and could not be hand scraped if worn. Necessarily, therefore, it must be surface ground. Whether grinding of this chilled surface should precede or follow the reconditioning process on other surfaces must then rest on the judgment of the scraper.

Sec. 27.62
OBJECTIVES: The Flat Slides of the Swivel Block

1. To be parallel to the plane of the original factory surface.
2. To be fitted to the flat ways of the knee with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

To avoid unnecessary shifting of feed screw, gears, bearings etc. it is advisable to attain OBJECTIVE NO. 1 as closely as possible. As a first step, the flat slides of the swivel block are spotted with marking compound transferred directly from the flat ways of the knee which for the purpose are coated with a film.

Inasmuch as we are assuming that the flat slides are relatively unused, it is a simple task to achieve OBJECTIVE NO. 1 by scraping straight down. As an aid to keeping the flat slides parallel to their original plane, we can use as a more or less reliable check point, the circular way of swivel block, shown in Fig. 27.61. This surface is usually suitable for this purpose because it receives comparatively little wear. However, conclusions to be drawn from use of this test must take into account the relative physical condition of the circular way.

In order to employ the circular way as a check point to test for parallelism in one direction, a set up similar to that shown in Fig. 27.62a should be arranged. Briefly the swivel block is placed in position on the knee. A TRY SQUARE is set vertically on the circular way. Then a DIAL INDICATOR clamped to a rod is inserted in the spindle. Next the SQUARE is brought up and adjusted to touch the DIAL button. By cranking the knee, the apparatus is moved upwards on the column. Readings are taken enroute. The tolerance allowed is shown in Fig. 27.62b.

The second test to observe how closely the flat slides are being kept parallel to their original plane in the other direction is made from the guiding way of the column. The apparatus and procedure employed are shown in Fig. 27.63a. The tolerance allowed is denoted in Fig. 27.63b. From the readings thus obtained the operator can judge quite closely the treatment required to accomplish OBJECTIVE NO. 1.

A third method of checking whether the flat slides are being scraped parallel to

the original factory plane, consists of using a dummy spindle inserted in the circular pivot hole and applying the swing-round test. The DIAL INDICATOR makes a circular sweep on the flat slides. A zero-zero reading around the circle will denote the correct alignment of the flat slides to axis of the pivot hole. This test may be performed at the bench by inverting the swivel block.

OBJECTIVES NO. 1 and NO. 2 should be attained simultaneously.

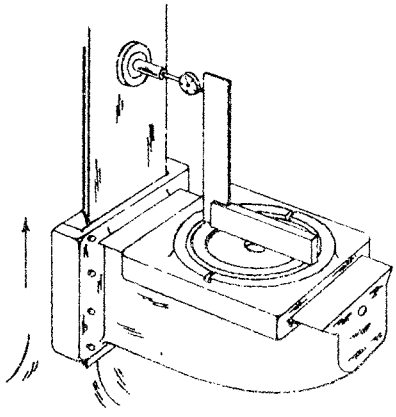

Fig. 27.62(a) Procedure used to determine if the flat slides of swivel block are being scraped parallel to their original plane. (Testing in longitudinal direction)

NOTE: To be certain that the groove (8) in Fig. 27.61 provides sufficient clearance for the swivel block, the Light Test (Sec. 18.11) should be applied.

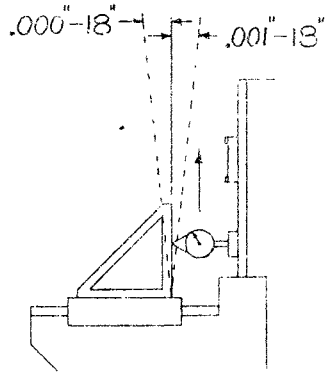

Fig. 27.62(b) Circular way square with column face. Maximum tolerance .001" in 18". (high at front)

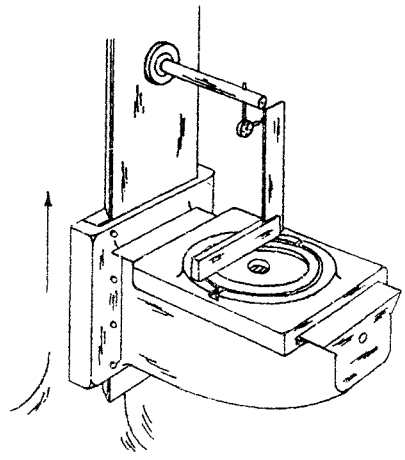

Fig. 27.63(a) Procedure to determine if flat slides of swivel block are being scraped parallel to their original factory-new plane. (Testing in transverse direction)

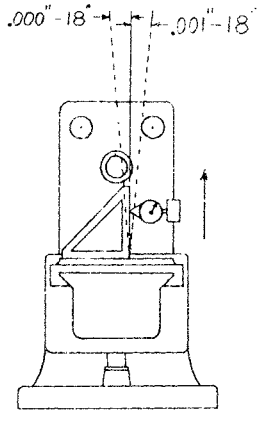

Fig. 27.63(b) Circular way square with guiding way of column. Maximum tolerance .001" in 18". (High at guiding way)

Sec. 27.63
OBJECTIVES: The Guided Slide of the Swivel Block

1. To be parallel to the plane of the original factory surface.
2. To be fitted to the guiding way of the knee with a surface quality of 10 - 15 bearing spots per square inch.
3. Axis of pivot to be aligned to axis of spindle. (Offset)

PROCEDURE:

The spotting operations on this surface are comparatively simple because we have available in the scrape-finished

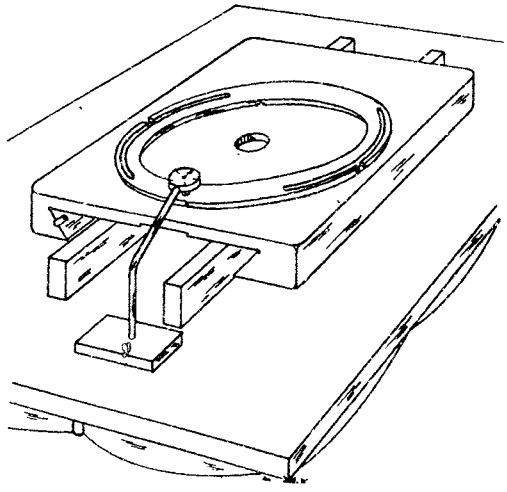

Fig. 27.64 Testing parallelism of circular way to flat slides of the swivel block.

surface of the guiding way of the knee, a perfect template. When coated with marking medium, the latter surface assists in forming the correct angle on the guided slide and facilitates the development of an area contact. (See Sec. 22.14 to Sec. 22.16) AN ANGLE STRAIGHT EDGE will be helpful in keeping the bearing surface flat.

The scraping operation, on the other hand, is much more difficult than appears at first glance. The template mentioned above gives us no help in achieving OBJECTIVE NO. 1. Yet this OBJECTIVE is important. Its close attainment obviates the unnecessary repositioning of auxiliary components which might otherwise "bind" and thus interfere with the smooth operation of this member.

The proper procedure in such circumstances is to scrape "straight down." However, this cannot be done intelligently without first carefully examining the surface for signs of wear. That portion of the bearing showing the least deterioration should be scraped more heavily. It takes keen analysis of the surface plus skillful manipulation of the scraper tool to do this effectively.

On some jobs it is advisable to produce a compound bearing on the slides of the swivel block. (See Sec. 19.11) If this course is adopted, the only change in procedure is to give the ends of the swivel block slides more bearing spots per square inch than the middle. In doing this, there must not be any sacrifice of surface flatness.

Before becoming engrossed in fulfilling OBJECTIVES NO. 1 and NO. 2 it would be advisable to notice again the requirements of OBJECTIVE NO. 3. In actual practice all three OBJECTIVES must be completed simultaneously.

OBJECTIVE NO. 3 has to do with correcting the misalignment of the axis of the pivot. This is referred to as offset. Offset, as we mentioned earlier, occurs in two directions, longitudinal and transverse. We are concerned with this matter now because the guided slide is a logical surface on which to correct the error in the longitudinal direction. It is the surface we have elected to use to compensate for Pivot Offset.

Methods of measuring the degree of offset are described in a later section. Plans for correcting this misalignment will also be explained subsequently. This is done so as not to encumber the PROCEDURE with excessive detail. We will, therefore, continue on and discuss the other bearing surfaces of this universal saddle member as though all OBJECTIVES for this surface have been satisfactorily completed.

Sec. 27.64
OBJECTIVES: The Tapered Gibbed Surface of the Swivel Block

(A tapered gib is to be attached)

1. To match the angular value of the gib way of knee.
2. To have a surface quality of 4 ~ 5 bearing spots per square inch.

PROCEDURE:

To spot the gibbed surface of the swivel block, a coating of compound is applied to the gib way of the knee member, which will act as the spotting tool. The transfer of the marking medium is accomplished by twisting the swivel block slightly askew so that the two surfaces are in contact. This is the quickest and most accurate method of obtaining a matching angle on the gibbed surface. In other words, the angle between the flat slides and gibbed surface of the swivel block should be identical to the angle between the flat ways and the gib way of the knee.

When working a surface to which a tapered gib will be fastened, a closely matching angle is a virtual "must." This was shown in Sec. 17.27.

Sometimes, due to design factors, it is not possible to oblique the swivel block so as to spot the gibbed surface in the manner described above. In such an eventuality, it is best to make up spotting templates, using as a pattern the angle formed by the flat ways and gib way of the knee. One template is spotted on the surfaces to obtain the correct angle, and the other template is processed from it. The latter template is then used to form a duplicate angle on the gibbed surface of the swivel block.

If the operator chooses not to undertake the job of making the templates, the angle between the flat way and gib way of knee should be carefully measured with a vernier protractor. The gibbed surface of the swivel block must then be worked to the identical angle as closely as possible, making frequent measurements with the vernier instrument.

NOTE: This is not a sliding bearing surface, hence the bearing quality stated in OBJECTIVE NO. 2 is entirely adequate.

Sec. 27.65
OBJECTIVES: The Circular Way of the Swivel Block

1. To be parallel to the flat slides.
2. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The circular way of the swivel block is shown in Fig. 27.61. Normally, this surface is not subjected to severe wear, but the original finish may have been damaged by grit or dirt entering between this surface and the circular slide of the saddle. In the course of time, this foreign matter will gouge deep circular grooves in the circular way as the saddle is turned to various positions.

In addition to this type of deterioration, the surface may also become defective from warping of the casting. Although ageing is sometimes the cause of this, it is more probable that the warp was induced by excessive pressure applied by the clamping bolts.

Routine spotting and scraping operations on the circular way are facilitated if the member is placed on a work bench. A SURFACE PLATE, if sufficiently large, is the most suitable tool for spotting this surface, although a STRAIGHT EDGE may be used, provided successive spottings are alternated in direction by 90°.

Testing for OBJECTIVE NO. 1 may be accomplished as shown in Fig. 27.64. Here the swivel block is placed on a SURFACE PLATE with the scrape-finished flat slides resting on identical PARALLELS. A DIAL INDICATOR affixed to a Surface Gage is brought to bear at a number of points on the circular way. A zero-zero reading indicates parallelism with the flat slides.

When the test described above is employed, a bi-lateral tolerance for parallelism amounting to .001" in 18" can be allowed on this surface. If the operator utilizes it, he must remember the amount and direction of the error in order to compensate for it on the saddle if that member is tested by a comparable method. (See Sec. 27.74) (Refer also to Sec. 23.16)

An alternative procedure to test for parallelism employs the technique illustrated in Fig. 27.62a and Fig. 27.63a. The tolerance allowed in each case is shown in Fig. 27.62b and Fig. 27.63b, respectively.

Both OBJECTIVES should be accomplished simultaneously.

This completes all the bearing surfaces of the swivel block. The tapered gib of the swivel block can now be fitted.

Sec. 27.66
OBJECTIVES: The Tapered Gib Piece of the Swivel Block

1. The straight side to be fitted to the gib way of the knee with a surface quality of 10 - 15 bearing spots per square inch.
2. The tapered side to be fitted to the gibbed surface of the swivel block with a surface quality of 4 - 5 bearing spots per square inch.

PROCEDURE:

It would be repetitious to discuss the production and fitting of a tapered gib piece since this subject was adequately treated beginning with Sec. 17.16. The reader is requested to refer back and refresh his memory.

Finish scraping of the tapered gib piece of the swivel block should not be undertaken until the following points are proved, namely that:

1. The alignment of the guiding way of knee to the column face is within the allowed tolerance.
2. The ways of the knee are flat and parallel.
3. The slides of swivel block are properly fitted to the ways of the knee.

These points will now be discussed.

Sec. 27.67
Testing the Guiding Way of the Knee for proper alignment with the Column Face

Now that the slides of the swivel block are scrape-finished there is presented an opportunity to make a more accurate check of the alignment of the knee guiding way to the column face. In the ordinary course of testing the knee member to which this universal saddle is being fitted, a procedure would have been followed similar to that described in Sec. 27.35.

The apparatus for that test included an indicating jig which provided only a L I N E contact on the guiding way of knee. (See Fig. 27.38a) It is expedient at this time to repeat the alignment test, utilizing as a gage the bearing surfaces of the swivel block which furnish the more dependable A R E A contact. Under these conditions, the accuracy of the test will be enhanced. Indeed, it will closely approach the precision of the final static tests to be performed later.

Assuming that we employed the procedure outlined previously in Sec. 27.35, the repetition of this alignment test will mark the third time it is being executed, hence any error detected should be very minute. The scraper must at all times strive to correct imperfections, however slight, which cause the recommended tolerance to be exceeded. (See Fig. 27.38b) Consequently, even if the fault discovered by this test is trivial, it should be remedied. If this is generally done, Cumulative Error is not likely to become a major problem.

Fig. 27.65a shows one method of applying the test above mentioned. A TRY SQUARE is clamped horizontally to the

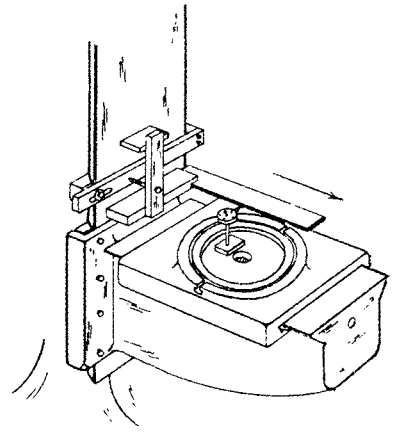

Fig. 27.65(a) Arrangement for testing guiding way of knee to face of column.

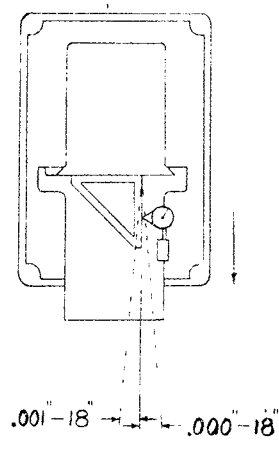

Fig. 27.65(b) Guiding way of knee to be square with column face. Maximum tolerance .001" in 18". (Opposing working pressure)

column face. Completing the set up is a DIAL INDICATOR fastened to a Surface Gage positioned on the swivel block.

After the gib is adjusted to proper sliding tension, the swivel block is moved out or in on the knee. The reading of the DIAL is noted as the contact button rides along the blade. Since the tolerance allowed for this bearing surface i.e. guiding way of knee, is unilateral (See Fig. 27.65b) care must be exercised that the reading of the DIAL INDICATOR is interpreted correctly. That is to say, the deflection of the pointer movement is interpreted in relation to the position of the TRY SQUARE, the direction of the swivel block traverse etc.

If a misalignment is in evidence, the guiding way of knee is reworked to correct it. As a direct consequence of this, the guided slide of the swivel block must also be rectified to accommodate the

slight change. We again refit the gib piece stopping, as before, just short of completion.

Sec. 27.68
Checking the Ways of the Knee for Parallelism

This test is conducted after the tapered gib has been well fitted but before it is finish scraped. To provide conditions assuring maximum precision it is advisable to clean and oil the ways of the knee and slides of swivel block. After mounting the block on the knee, the gib is inserted and adjusted for sliding pressure. Next the swivel block should be moved in and out on the knee by hand and checked for signs of bind or slack. If none is found, the ways of the knee can be considered parallel. Additional scraping is required if either sticking or looseness is noted on these surfaces. (See Sec. 22.11 for sliding Member Test.)

Sec. 27.69
Testing the Fit of the Swivel Block Slides to the Knee Ways

In addition to checking the parallelism of the knee ways, the operator is advised to test at this time for convexity, "rock" of the swivel block on the knee. The Shake Test (Sec. 22.5) has been discussed in detail elsewhere but its application in the present instance may be described briefly as follows:

While an assistant attempts to twist or "rock" the swivel block, the operator feels at the four corners in succession for any movement between this member and the knee. If no motion is detected, over and above a permissible minimum, the ways may be considered sufficiently flat and the slides are judged well fitted. It is now practicable to scrape-finish the gib piece.

A few miscellaneous operations are performed next. Touching up the ways of the knee is essential; frosting these surfaces is optional.

Sec. 27.70
The Saddle Member of the Universal Saddle

The saddle, or upper section, of the universal saddle has four surfaces which are scraped. These surfaces will be treated in the same order that they are enumerated, viz:

1. The flat ways
2. The angular guiding way
3. The angular gibbed surface
4. The circular slide.

The accompanying illustration, Fig. 27.66, shows these surfaces.

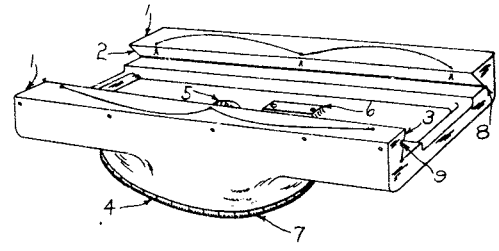

Fig. 27.66 View of the saddle showing principal bearing surfaces and other features.

(1) flat ways (2) guiding way (3) gibbed surface (4) circular slide (5) pivot hole (6) table nut boss (7) angular graduations (8) groove (9) gib adjustment screw slot

Sec. 27.71
OBJECTIVES: The Flat Ways of the Saddle

1. To be parallel to the original factory surface.
2. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

To avoid any radical shifting of bearings, feed screws, shafting etc., it is ad-

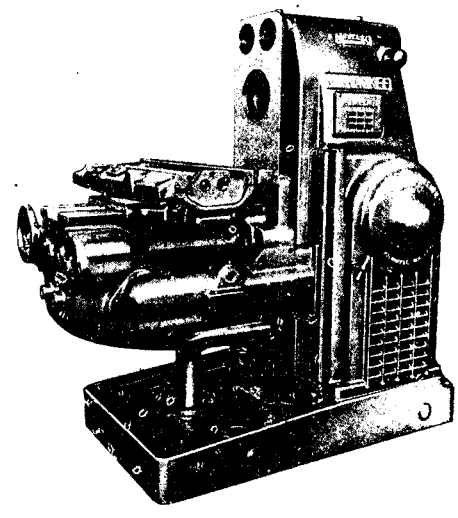

PLATE 48. Column plus knee plus swivel block plus saddle of horizontal milling machine. (Courtesy - Kearney & Trecker Corp.)

visable that OBJECTIVE NO. 1 be attained as closely as practicable. Therefore, as a first step, the flat ways of the saddle, shown in Fig. 27.67, are examined to determine what portions are least worn. To facilitate this inspection, the surfaces are spotted with a SURFACE PLATE and a STRAIGHT EDGE applied alternately.

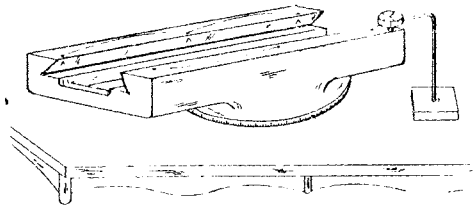

Fig. 27.67 Testing the flat ways of the saddle at all four corners for parallelism with the circular slide.

We have already remarked that one alternative method of producing a flat surface that satisfies OBJECTIVE NO. 1 is to scrape "straight down." (See Sec. 23.21) How successful the operator who adopts this course will be depends largely on his skill and experience. Even an expert mechanic would be handicapped if scarcely a trace remained of the original surface. In such a case results will be based primarily on guess work, unless instrumental surveys can be made from a check point.

One handicap in treating the flat ways is that there is no convenient and reliable check point on the upper side of the saddle from which to test for OBJECTIVE NO. 1 with exactness. A possible check point on an adjacent surface, the circular slide, is feasible because usually it is only slightly worn. Thus just a few cycles of spotting and scraping may be required to remove all burrs from the circular slide and establish a fairly flat surface to which the test for parallelism may be directed.

If this plan is adopted, the circular slide is placed in contact with a SURFACE PLATE as shown in Fig. 27.67. Then measurements are made from the SURFACE PLATE to the four corners of the flat ways, in turn. A DIAL INDICATOR attached to a Surface Gage is appropriate for this work. The test is repeated at intervals as the work on the flat ways progresses. When the readings at all four corners are similar, or nearly so, it signifies that the flat ways approximate OBJECTIVE NO. 1. As stated above, the truth of this check will be dependent on the condition of the circular slide.

Another possible check point would be the pivot hole. If a dummy spindle with attached DIAL INDICATOR is inserted in the hole, the apparatus can be used to make a swing round test. A zero-zero reading at four points on the flat ways will aid in achieving OBJECTIVE NO. 1.

Both OBJECTIVES should be completed simultaneously.

CAUTION: Care should be exercised when scraping in proximity to the oil grooves.

Sec. 27.72
OBJECTIVES: The Angular Guiding Way of the Saddle

1. To retain the original angle.
2. To be parallel to the original factory surface.
3. To have a surface quality of 10 - 15 bearing spots per square inch.
4. Center T-slot to be aligned to axis of pivot. (Offset)

PROCEDURE:

The correct angle required by OBJECTIVE NO. 1 is determined by an inspection of the angular guiding way of the saddle and by a similar examination of the angular guided slide of the table. From these findings a decision as to the angle is made, and the guiding way is scraped accordingly. A Vernier Protractor will be useful in measuring the angle initially and in determining if the scraping effort is achieving the desired results.

It is highly desirable that OBJECTIVE NO. 2 be secured as nearly as possible, and for the same reasons given when treating the flat ways of the saddle. (Sec. 27.71) On members not too badly worn there is usually some trace of the original surface, such as scraping tool marks, to serve as a guide. However, it should be pointed out that the attainment of OBJECTIVE NO. 2, particularly on a badly worn machine, is very difficult. One possible check point is the table

screw threaded through the table nut. An acceptable substitute for the table screw is a precision test bar pushed through the table nut, then centered and locked. If either of these check points is used, proceed as follows:

The saddle is removed to a work bench for convenience. Then a DIAL INDICATOR is attached to an indicating jig. The apparatus is set so it straddles the flat ways, with the jig supports touching the angular guiding way of the saddle,

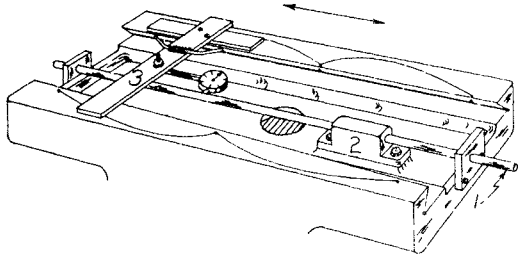

Fig. 27.68 Using a table screw, or test bar, as a check point to keep guiding way of the saddle parallel to original plane.

(1) test bar (2) table nut (3) indicating jig.

as shown in Fig. 27.68. Next the contact plunger of the DIAL is brought against the test bar at the horizontal diameter. This arrangement for determining the rate of progress must be repeated periodically as the scraping work proceeds. If a zero-zero reading is obtained when the device tests at each end of the test bar, the angular guiding way is parallel to the axis of the test bar. This signifies the accomplishment of OBJECTIVE NO. 2. (Incidentally, this method could be used on the flat ways previously discussed in Sec. 27.71. The contact button would in that case be brought to bear on the vertical diameter of the test bar)

Another alternative procedure, which is feasible only if the surface has not previously been altered by scraping, could be performed as follows:

The universal saddle is placed on the knee. The table is mounted and the table gib is inserted and adjusted for sliding pressure. A DIAL INDICATOR is placed on the table top in such a way that the plunger is in contact with the column face. As the table is moved longitudinally, the saddle is adjusted until the DIAL reads zero-zero, or as close to it as possible. The guiding way of the saddle is now as near to being parallel with the column face as it is feasible to make it. The saddle should be locked in this position.

After removing the table, holes are drilled and tapped in the back flat way i.e. the flat way nearest to the column face. A tool maker's button is fastened at both ends of this surface. It is now possible to adjust each button till it is equi-distant from the column face, as shown in Fig. 27.69. (The buttons now parallel the table movement.) The buttons are then locked securely and may be used as a check point when the saddle is removed for purposes of scraping the guiding way. Fig. 27.70 shows an indicating jig being used to check the parallelism of the guiding way with the original surface utilizing the tool maker's buttons as a check point.

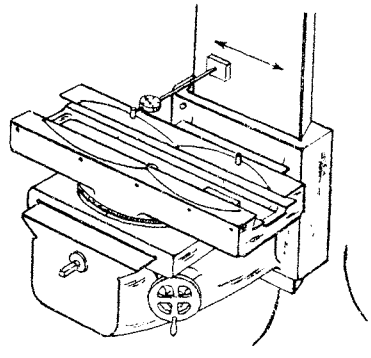

Fig. 27.69 Adjusting tool maker's buttons equidistance from face of column.

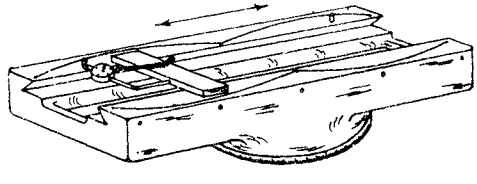

Fig. 27.70 Testing the guiding way of the saddle for parallelism with the original factory plane. Tool maker's buttons used as a check point.

With the check point established, we are now in a position to scrape the guiding way of the saddle. It is advisable to test frequently the results of the scraping by checking from the guiding way to the tool buttons with the indicating jig and attached DIAL.

OBJECTIVE NO. 4 deals with the misalignment of the center T-slot.

The guiding way of the saddle is one of the surfaces which can be built up to compensate for any misalignment between the center T-slot of the table and the axis of the pivot of the saddle. For this reason it is suggested that the scraper turn to Sec. 27.75 (Offset of Pivot) to determine if the discussion there is pertinent to his present problem.

This system is followed because explaining the subject of pivot offset and the methods of correcting it would amount to a considerable digression from the present PROCEDURE: We will, therefore, postpone this discussion to a later paragraph and continue with the next bearing surface in the sequence as though this alignment had been accomplished.

It should be emphasized again that all four OBJECTIVES must be completed simultaneously.

Sec. 27.73
OBJECTIVES: The Tapered Angular Gibbed Surface of the Saddle

(A tapered gib piece is to be used)

1. To retain the original factory taper and to duplicate the original angle.
2. To have a surface quality of 4 - 5 bearing spots per square inch.

PROCEDURE:

The reader will note that OBJECTIVE NO. 1 consists of two requirements. The first has to do with the taper and is discretionary. The second, pertains to the angle, and should be attained if possible. It is a matter of choice with the operator whether to dispense with the first requirement. Whatever decision is made would depend upon whether the old gib piece is to be reused or discarded in favor of a replacement.

Ordinarily, when feasible, it is the better practice to keep the old gib, as this course saves the considerable work of making a new one. However, when a warp is evidenced in the gibbed surface and heavy scraping is necessary to render the surface flat, it is very probable that the old gib piece will prove to be too small. This is particularly true when other surfaces, which also influence the size of the gib slot, are also heavily rescraped. In such a case, we may disregard the existing taper and scrape this surface to any chance taper that evolves while obtaining flatness. Usually the taper generated will be quite close to the original taper anyway.

Since warping of the gibbed surface is our principal cause for concern, we test the surface by spotting it with an ANGLE STRAIGHT EDGE. If the markings indicate flatness, and no sign of this defect is apparent, little work is called for, except possibly picking off a burr or two.

On the other hand, when a radical correction is necessitated, the second requirement of OBJECTIVE NO. 1 should not be overlooked. The first step is to measure the existing angle of the gibbed surface, which would not be altered even by a warp. This angle is maintained by frequent checks with a vernier protractor as the scraping proceeds.

The foregoing procedure looking toward the preservation of the original angle is advisable for two reasons. First, it is recommended so that the angular value of the gib slide of the table member will not require a major alteration to match some new angular value of the gibbed surface.

Second, it is recommended in order to avoid fitting a tapered gib piece with the troublesome transverse taper, should the gib slide of table not be scraped accurately to a matching angle.

Operations should be synchronized so that both OBJECTIVES are executed at the same time.

Sec. 27.74
OBJECTIVES: The Circular Slide of the Saddle

1. To be fitted to the circular way of the swivel block with a surface quality of 10 - 15 bearing spots per square inch.
2. To be parallel to the flat ways of the saddle.

PROCEDURE:

Fig. 27.71 shows the circular slide of the saddle. This is not a difficult surface to scrape. Indeed in many examples encountered, it will not even be seriously worn. A SURFACE PLATE is the appropriate spotting tool, but it may be alternated with a STRAIGHT EDGE. In addition, we should occasionally use the mateing surface, or circular way of the swivel

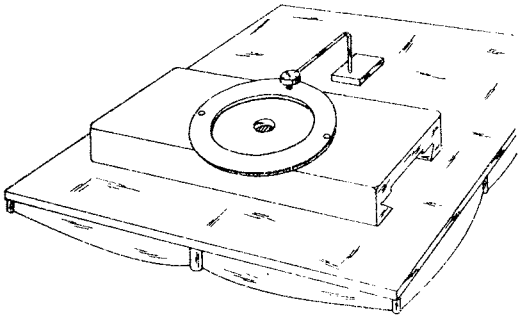

Fig. 27.71 Method of checking parallelism of circular slide of the saddle to flat ways.

block, as a template since OBJECTIVE NO. 1 calls for fitting.

The appropriate set up to check for OBJECTIVE NO. 2 requires placing the saddle section on a large SURFACE PLATE, as represented in Fig. 27.71. The contact plunger of a DIAL INDICATOR is brought to bear on the circular slide, as the figure shows. As the Surface Gage with its attached instrument is moved to different positions, parallelism is indicated if identical readings are registered on the DIAL at each point tested.

A tolerance of .001" in 18" is allowed for the alignment specified in OBJECTIVE NO. 2. In utilizing this tolerance care must be exercised not to induce a Cumulative Error. Remember that we undoubtedly availed ourselves of at least a part of a similar tolerance when scraping the circular way of the swivel block. (See Sec. 27.65) Consequently, the tolerance now used for this present surface must be applied in the contrary direction. Thus the effect of the retained error of one surface is nullified by opposing an approximately equivalent tolerance on the other surface.

An alternative testing procedure is described below. Assemble the saddle and swivel block on the knee and repeat the alignment tests illustrated in Fig. 27.62a and Fig. 27.63a. The present set ups are the same as shown except that the SQUARE is now positioned on the flat ways of the saddle.

If the amount of tolerance utilized on the circular slide of the saddle correspond with, but is opposed to the accepted error on the circular way of the swivel block, then the alignment of this subassembly will be within the allowable tolerance indicated in Fig. 27.62b and Fig. 27.63b. Quite possibly the same reading would be observed on the DIAL INDICATOR as was obtained when the tests were originally performed with the TRY SQUARE stationed on the knee flat ways. A corresponding set up is shown in Fig. 27.36a and Fig. 27.37a.

This completes all scraping work on the Universal Saddle.

Sec. 27.75
Offset of the Pivot Axis on Universal Saddles

We will now take up the subject of offset of pivot axis as promised in an earlier paragraph. The situation briefly is this.

The lower section and the upper section of the universal saddle are centrally connected by a pivot. The upper section swivels horizontally about the axis of this pivot. The pivot may take the form of a bushing through which a shaft projects. The shaft extends from the knee member and transmits motion to power the table member with automatic feed.

Helical milling is possible on a machine equipped with a universal saddle. However, for the milling cutter to generate a true and undistorted profile, it is essential that:

1. The axis of the spindle
2. The axis of the pivot
3. The center T-slot of the table

be in line with respect to each other within close limits. Fig. 27.72 and Fig. 27.73 clearly show this alignment. Only a small bilateral tolerance is permissible in this alignment, if undue distortion of the generated profile is to be avoided. As a consequence, rescraping and aligning a universal saddle presents a particularly difficult problem to the scraper.

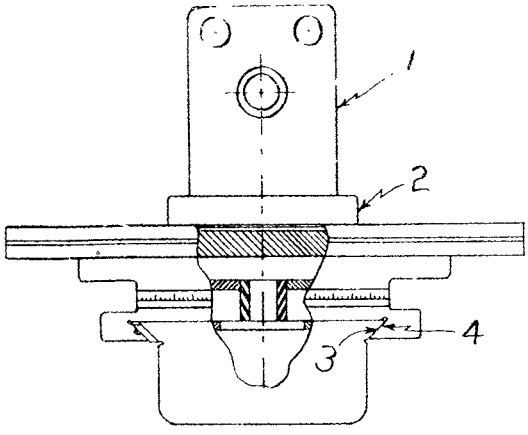

Fig. 27.72 Sectional view of horizontal milling machine showing alignment of axis of spindle to axis of pivot.

(1) guiding way of column (2) guided slide of knee (3) guiding way of knee (4) guided slide of swivel block

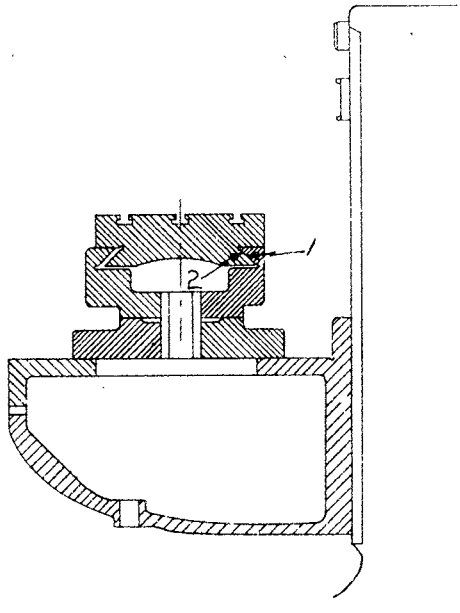

Fig. 27.73 Sectional view of horizontal milling machine showing alignment of center T-slot with axis of pivot.

(1) guiding way of the saddle (2) guided slide of table

The reason, briefly, is this: Any offset originally present in the three elements, above mentioned, becomes progressively worse as each bearing surface that influences their alignment to each other is scraped true. Thus during a rescraping job on the Horizontal Mill, the axis of the spindle is immovable but the axis of the pivot and the center-line of the center T-slot move from their original location to a new position as certain bearing surfaces are rescraped.

To clarify this matter of offset, let us use as an example the universal saddle attached to the Horizontal Milling Machine discussed in this chapter. We will assume in our imaginary case that the alignment of the machine, when new, was accurate within the allowed tolerance. That is to say, the axis of the pivot was aligned with the axis of the spindle, and the axis of pivot passed midway between the two sides of the throat of center T-slot i.e. intersecting the center-line of center T-slot.

In short, two alignments are involved. Taking them in order, we will consider, first, what bearing surfaces affect the alignment of the axis of the pivot in the longitudinal direction with respect to the axis of the spindle; and second, what surfaces influence the alignment of the center-line of the center T-slot in the transverse direction, with reference to the axis of the pivot.

Sec. 27.76
Offset Longitudinally

We find that on the Horizontal Milling Machine under discussion, there are four surfaces that contribute, in varying degree, to the misalignment of the axis of the pivot with respect to the axis of the spindle.

With all observations made from a position at the front of the machine represented in Fig. 27.72 we see that the pivot moves to the L E F T with reference to its original position, as each of the bearing surfaces in the following group is scraped, viz:

1. The guiding way of the column
2. The guided slide of the knee
3. The guiding way of the knee
4. The guided slide of the swivel block.

Thus, in the model studied, it is obvious that the error is cumulative. The net effect of scraping these aforementioned surfaces is that the axis of the pivot moves to the LEFT in relation to its original position. We can say, therefore, that any offset in alignment of the axis

of the pivot with respect to the axis of the spindle is due to natural wear and the necessary rescraping of the four surfaces mentioned above, and is unavoidable.

Sec. 27.77
Offset Transversely

A somewhat similar problem is faced with reference to the alignment of the center T-slot to the axis of the pivot. As metal is removed from the surfaces enumerated below, the center-line of center T-slot moves inwardly towards the column face thereby losing its original alignment with respect to the axis of pivot. In short, the alignment of the center T-slot to the axis of pivot worsens as the following two surfaces are treated, viz:

1. The guiding way of saddle.
2. The guided slide of table.

This is shown in Fig. 27.73.

Sec. 27.78
Interpretation

How serious will be the misalignment between the spindle axis, the center-line of the center T-slot, and the pivot axis depends solely upon the amount of metal removed from each bearing surface influencing these features. As far as the Horizontal Miller now being discussed is concerned, the effect in all cases will be additive.

The reader should not construe the foregoing to mean that the net movement of the pivot axis on all milling machines is always to the LEFT, although in the specific example just considered, this was so.

The location of the gib piece as to the right or left side on a particular member will control the direction that the misalignment of the pivot axis takes. That is to say, the set-over is always towards the gibbed side of the member.

As for the center-line of the center T-slot, its displacement is always inwardly towards the face of the column.

Due to the difficulty of accomplishing the alignments, some shops deliberately ignore the offset of the pivot axis when reconditioning milling machines having a universal saddle. Such a practice is often tolerated because it will be found that the inaccuracy of a helical milling cut, produced on such a machine, is acceptable on most types of work unless, of course, the amount of metal removed from the several bearing surfaces was excessive. However, even in severe cases, there are several methods of minimizing this problem which the scraper should become familiar with.

Sec. 27.79
Building up a Surface to Rectify Offset of Pivot

For those occasions when the universal machine must be restored to the original accuracy in all alignments, it will be necessary to build up certain bearing surfaces to accomplish this. Again utilizing the Horizontal Milling Machine under discussion as an example, the following corrective steps are feasible to align the axis of the pivot with the axis of the spindle.

1. Adding Metal Strips:

The alteration to be effected consists in part, of machining off, say a 1/2" thick slab from the guided slide of the swivel block. Then to this slide is bolted or pinned a strip of similar metal slightly thicker than the slab just removed. The rule is to allow for sufficient thickness so that the built-up surface can be scraped to the required bearing quality and at the same time eliminate the pivot offset with respect to the spindle. The guided slide is then aligned and tested in the usual fashion.

To counteract any detrimental shift in the alignment of the center T-slot of the table with respect to the axis of the pivot, that may develop during the scraping process, a similar procedure is suggested. As before, a strip of metal about 1/2" thick is machined from the appropriate surface i.e. the guiding way of the saddle. A strip of metal of somewhat thicker dimensions is then bolted and pinned to this surface. The built-up surface is scraped until the guiding way of the saddle satisfies all necessary OBJECTIVES, including the correct positioning of the center T-slot with respect to the axis of the pivot.

2. Metalizing:

In lieu of machining away metal in preparation for the attachment of metal strips, the worn bearing surface is sometimes built up by a process known as metalizing. Metal spraying, which is a branch of the welding art, consists of applying molten metal in vapor form to the surface to be built up. Under ordinary conditions, a coating of metal of sufficient thickness may be applied quite easily to a bearing surface to compensate for wear. The alignment to the pivot axis can then be accomplished without much difficulty by the normal process of rescraping the built-up bearing surface.

Alignment Tests for Offset of Pivot

After the surfaces have been built up by one of the methods discussed above, the surfaces are scraped to rectify the errors of offset. As the work proceeds two alignment tests are conducted periodically. Their purpose is to ascertain how closely the spindle axis, the center T-slot, and the pivot axis align with respect to each other. These tests will be discussed separately in the two following sections:

Sec. 27.80
Testing Axis of Pivot for Offset with Respect to Axis of Spindle

(Horizontal Milling Machine.)

PROCEDURE:

In practice this test is usually conducted before any scraping, other than removal of burrs, is attempted on the swivel block.

We will assume that we have decided to cancel the aggregate error of the four surfaces contributing to the offset of the pivot in longitudinal direction (See Sec. 27.76) by corrective measures applied exclusively to the guided slide of the swivel block.

The problem of determining the error is two-fold:

1. What allowance should be made for scraping the guided slide of swivel block to a good fit with the guiding way of knee and providing adequate bearing quality?
2. What does the measurable offset amount to?

The first question cannot be answered definitely though a fair estimate can be made.

The second query can be answered more exactly as we conduct the alignment test.

The sum of the two answers will indicate the error to be corrected by building up the guided slide of swivel block.

The set up for the alignment test is made as follows:

When the knee member has been scrape-finished, place the universal saddle in position on the knee member. Insert the old gib piece of the swivel block and adjust for sliding tension.

Align the zero (0°) degree graduation on the saddle with the marker on the swivel block. Next insert a precision test bar in the tapered hole of the spindle, make a run out test, and turn the bar so that the mean position of eccentricity error lies in the horizontal plane. Mount a DIAL INDICATOR rigidly on the flat ways of the saddle, as shown in Fig. 27.74a.

Adjust the universal saddle along the knee until the axis of the pivot hole is approximately below the free end of the test bar. Touch the plunger of the instrument to the free end of the test bar at the horizontal diameter. Do this by elevating the knee until the DIAL pointer reaches its maximum deflection. Spin the face of DIAL zeroing it.

Next the saddle is rotated exactly 180°. (See NOTE:) Making this maneuver may necessitate pulling the universal saddle forward so that the end of the swivel block can clear the column.

When the turn-about is made, the universal saddle is moved back so that the plunger of the instrument again touches the free end of the test bar at the horizontal diameter. Due to the 180° swing this will be on the opposite side of the bar. The reading of the DIAL is noted, and the difference between the two readings will indicate the current amount of offset of the axis of pivot.

With the information obtained from the test coupled with the estimate allowing for proper fit, the necessary work re-

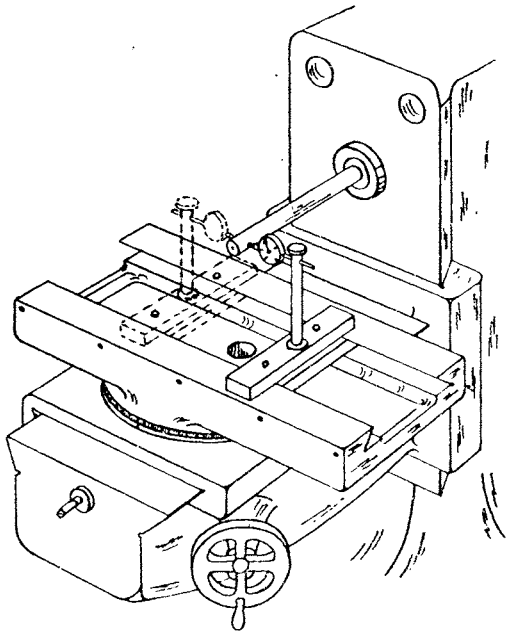

Fig. 27.74(a) Testing the amount of offset of the axis of the pivot to the axis of the spindle.

quired to build up the guided slide of the swivel block to scrape-finish at this figure may be undertaken. After being built up, the guided slide is scraped and aligned to accomplish all of the OBJECTIVES listed in Sec. 27.63. The tolerance allowed for pivot offset is shown in Fig. 27.74b.

The remaining surfaces of the swivel block may now be scraped and aligned as mentioned previously.

NOTE: Use is made of the graduations on the saddle to register the 180° swing

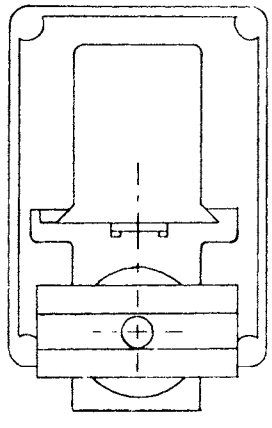

Fig. 27.74(b) Offset of pivot axis to axis of spindle. Maximum tolerance .002".

mentioned earlier. Though precision is essential, a deviation of a fractional part of a degree will not appreciably affect the measurement of the offset. When the graduations are not usable, the following procedure may be substituted, viz:

The table is placed in position on the universal saddle, and the table gib is inserted and adjusted for sliding tension. The saddle-table assembly is arranged so that the table movement parallels the column face. i.e. table travel square with axis of spindle. This alignment is verified if a DIAL INDICATOR fastened to the table top reads zero-zero traveling from side to side of column face.

A line is scribed on the swivel block to align with the zero (0°) degree graduation on the saddle.

The table is pulled longitudinally until it is flush with one end of the saddle. Then the saddle is swung an estimated 180°. A DIAL INDICATOR is again clamped to the table top, and its plunger is adjusted to touch the column face. The saddle is adjusted until the table movement once more registers a zero-zero reading from side to side of the column face. When this alignment is obtained, the saddle has been rotated exactly 180°.

A line is now scribed on the saddle to align with the marker line previously scribed on the swivel block. With these identification marks on the universal saddle, it is a simple matter to rotate the saddle precisely 180° as required by the test.

Sec. 27.81
Testing the Center T-slot for Offset with Respect to Axis of the Pivot

(Horizontal Milling Machine.)

PROCEDURE:

In routine practice, this test is conducted following the completion of the swivel block of the universal saddle, but before any scraping is started on the saddle.

The reliability of the test will be dependent upon the ability of the scraper to estimate accurately what the shift in the position of the Center T-slot, measured in thousandths of an inch, will be after the guiding way of the saddle and the guided slide of the table are fitted to each other. This is in addition to whatever error is disclosed by the test itself.

If the operator doubts his ability to make this estimate accurately, it can be deferred until these two surfaces have had some preliminary scraping leading to a better fit between them, when a more exact answer can be supplied. However, if the latter course is adopted, some duplication of effort will be unavoidable. The work performed on the semi-finished surface is wasted as it must be built up sufficiently to overcome the offset, then scraped anew to effect a good bearing. Inasmuch as the test is simple, it should be conducted. Here we fall back on the altogether logical assumption that the more information available to the scraper, the more intelligently he can proceed with his work.

Essentially what we must do is to find answers to two questions, namely:

1. What allowance should be made for scraping the guiding way of the saddle and guided slide of the table to a mutually good fit and adequate bearing quality?
2. What does the measurable offset amount to?

The sum of the two answers will indicate the error to be corrected by building up the selected surface, i.e. the guiding way of saddle.

Taking them in order, we first inspect the condition of the two bearing surfaces above mentioned. These are the surfaces which will affect the position of the center T-slot with reference to the axis of pivot. By examining them an estimate can be made of the quantity of metal that must be scraped off to provide the necessary characteristics.

Secondly, to determine the degree of offset we arrange the set up illustrated in Fig. 27.75a. It shows the parts assembled and the table gib inserted and adjusted for sliding tension.

Having inserted a test bar in the tapered hole in the spindle, a run out test is conducted, and the bar turned to place the mean position of eccentricity error at the horizontal diameter.

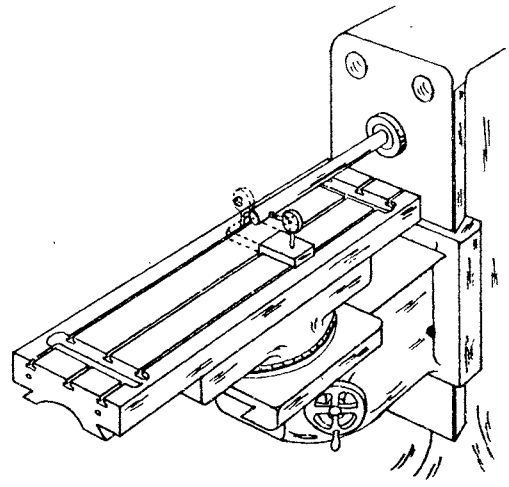

Fig. 27.75(a) Set up used to determine offset of center T-slot with axis of pivot.

The saddle-table assembly is now swiveled 90°, i.e. square with column face. To perform this movement it may be necessary to pull the assembly forward on the knee so that the saddle and table members will clear the column.

Make up a square edge jig and attach a DIAL INDICATOR. Insert the jig in the center T-slot pressing it against one side of the throat. Place the button of the instrument on the test bar at the horizontal diameter. Move the jig back and forth along the T-slot meanwhile adjusting the saddle until an exact zero-zero reading is observed. The T-slot is now parallel with the axis of the spindle. Clamp the saddle to prevent further movement and note the reading on the face of the DIAL. Remove the jig, turn, and replace it in the center T-slot, but against the opposite side of the throat. Compare the new reading on the DIAL with the previous one. Any difference between them indicates the current amount of offset of the Center T-slot with respect to the axis of the pivot.

With the information obtained from the test, plus the estimate previously made, the necessary work required to built up the guiding way of the saddle may be undertaken. With this phase concluded, the guiding way of the saddle can be

scraped and aligned to accomplish all of the OBJECTIVES listed in Sec. 27.72.

The tolerance allowed for the alignment of the Center T-slot to the axis of the pivot is shown in Fig. 27.75b.

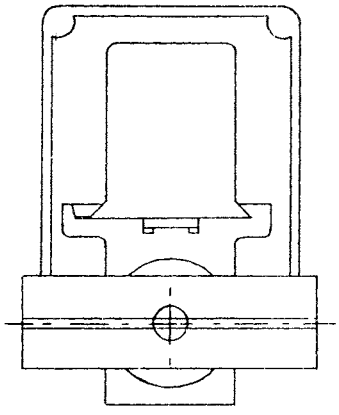

Fig. 27.75(b) Offset of center T-slot to axis of pivot. Maximum tolerance .002".

Sec. 27.82
The Table

The table of the horizontal milling machine is an oblong casting that slides longitudinally on the saddle. T-slots are milled in the top and front surfaces of the table for the purpose of fastening various fixtures and work pieces, and for positioning table stops.

There are seven separate table surfaces to be treated by the scraping operator. They are enumerated below in the preferred order of operations and illustrated in Fig. 27.76a.

Top surface
Front surface
Back surface
Flat slides
Guided slide
Gib slide
End surfaces (two)

(In the machine described here the table member is gibbed to the saddle member by a flat gib.)

Sec. 27.83
Selecting the Check Point

The Final Alignment Tests of the completed machine are performed from the top of the table member directly to the Datum Point of the machine i.e. the spindle, or indirectly to other check points, such as the face of the column etc. However, in scraping the table, the Datum Point is not utilized. It is far more convenient to use the center T-slot in the top of the table as a check point to assure that the several surfaces are square with, or parallel to another surface, as required by the OBJECTIVES.

EXPLORATORY EXAMINATION:

A general inspection of the table should precede any other work. Then the burrs

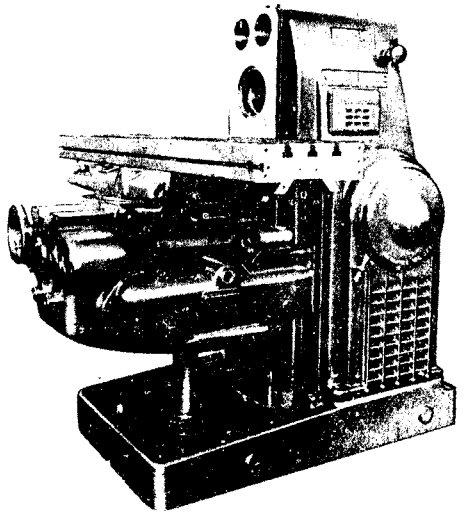

PLATE 49. Column unit plus universal saddle plus table, of horizontal milling machine. (Courtesy - Kearney & Trecker Corp.)

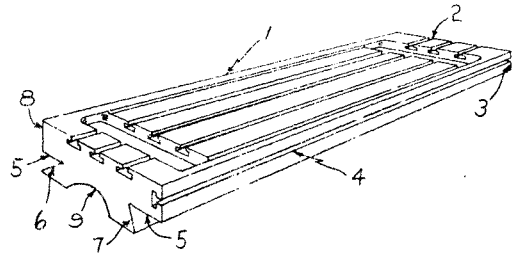

Fig. 27.76(a) Table of horizontal milling machine.

(1) top surface (2) top "T" slots (3) front surface (4) front "T" slot (5) flat slide (6) guided slide (7) gib slide (8) back surface (9) end surface

are removed with a burr file. Next each surface is spotted with a STRAIGHT EDGE or SURFACE PLATE after which the markings are analyzed. Having obtained an impression of the over-all requirements from this examination, the operator should schedule the work as suggested above.

Sec. 27.84
OBJECTIVES: The Top Surface of the Table

1. To be square with the center T-slot.
2. To be a true flat plane.
3. To have a surface quality of 5 - 25 bearing spots per square inch.

PROCEDURE:

The operator should first direct his attention to the T-slots on the top surface, illustrated in Fig. 27.76a. The function of the center T-slot is to position the fixtures i.e. dividing head, milling machine vise, etc. These attachments are designed to align themselves automatically when their tongues are inserted in the center T-slot. Since, in many cases, the T-slots are burred and roughened, it is advisable to clean them up with a file before going further. In removing the burrs, take care not to widen the throat of the T-slot, or it will be necessary to make new tongues for the fixtures. Fig. 27.76b shows the tolerance.

To check for OBJECTIVE NO. 1, it will be necessary to have a piece of flat stock ground parallel so that it is a light press fit in the center T slot, as shown in Fig. 27.77a. The flat piece is inserted in turn at each end of the slot as well as in the middle. A 6" TOOL MAKER'S SQUARE is placed successively against the flat stock. Then using pieces of feeler stock, a check is made to determine if the permissible tolerance indicated in Fig. 27.77b is exceeded.

When it is known how much error is present, corrective scraping may be initiated on the table top. The alternate application of a SURFACE PLATE and STRAIGHT EDGE for spotting purposes will help in fulfilling OBJECTIVES NO. 1 and NO. 2. Flatness as usual will be indicated by uniform coloration and distribution of the markings.

The critical reader will note the considerable latitude allowed for bearing quality in OBJECTIVE NO. 3. The explanation is that there is a wide variation in the type of service demanded of the table. If a crude fixture is to be clamped to the table, the lesser figure will do well enough. On the other hand, should the top surface be intended to double in the capacity of a SURFACE PLATE for measuring purposes on work being machined, then the greater figure must be equalled or bettered.

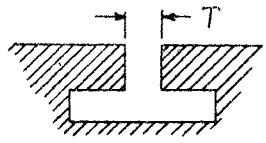

Fig. 27.76(b) Width of throat of "T" slot determines the dimension of tongues of auxiliary parts. A tolerance of plus .001" is permissible.

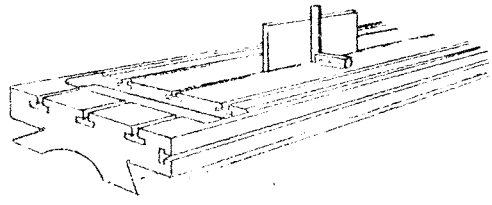

Fig. 27.77(a) Method of testing alignment of top surface of table with center "T" slot.

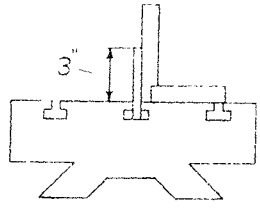

Fig. 27.77(b) Top of table square with "T" slot. Maximum tolerance .001" in 3".

The only special precaution to be observed in scraping this surface is to approach the edges of the slots in the approved manner described in Sec. 6.11. Scraping operations on this member are most conveniently performed at a bench.

All of the OBJECTIVES for this surface must be attained at the same time.

Sec. 27.85
OBJECTIVES: The Front Surface of the Table

1. To be square with the table top.
2. To be parallel with the axis of the

center T-slot.
3. To have a surface quality of 5 - 25 bearing spots per square inch.

The front surface is often used to align work pieces on the milling machine table, preparatory to machining. It is essential, therefore, that the alignment of this surface with the center T-slot be very accurate.

PROCEDURE:

A STRAIGHT EDGE, a SURFACE PLATE, and a RIGHT ANGLE TEMPLATE are the tools employed to accomplish OBJECTIVES NO. 1 and NO. 3. In lieu of the TEMPLATE, a TOOL MAKER'S SQUARE can be substituted to check the angle, though it is not so satisfactory.

The T-slot, dividing the front surface of the table, is not critical as it usually acts only as a clamping slot for the table stops. It requires no special treatment except the ordinary care in scraping to the perimeter of the slot.

To check the table for the parallelism required by OBJECTIVE NO. 2, proceed as follows: A ground piece of flat stock is inserted into the center T-slot on top of the table. Then a measurement is made from the front of the table to the flat piece as shown in Fig. 27.78a. A DIAL INDICATOR attached to the TEMPLATE mentioned above can be utilized for this purpose.

Readings are taken at both ends of the table, as for example, at points (a) and (b). The readings must be similar before the front surface is parallel to the center T-slot. A small tolerance is allowed on this surface as illustrated in Fig. 27.78b.

NOTE: If a RIGHT ANGLE TEMPLATE is not available, the operator should have no difficulty in designing a suitable indicating jig for testing the alignment of this surface as many examples have been given previously.

Sec. 27.86
The Back Surface of the Table

When reconditioning the horizontal milling machine table, the back surface, in many cases, is not scraped. There are, however, advantages in having this surface parallel to the center T-slot. For example, it is an aid in setting up work and it is also useful as a surface from which to make measurements. Whether or not the operator scrapes the back surface of the table, will very often be determined by the nature of the work the reconditioned machine is scheduled to perform. With a machine tool slated for factory production, it is seldom thought worthwhile but in the case of tool room equipment, it is customary to do so.

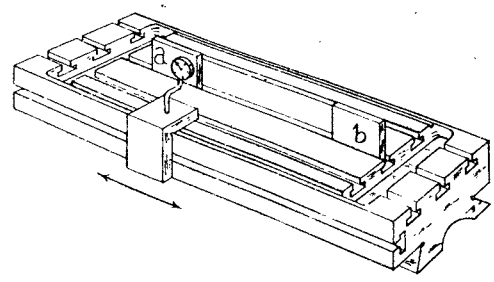

Fig. 27.78(a) General arrangement for testing front surface of table to center "T" slot.

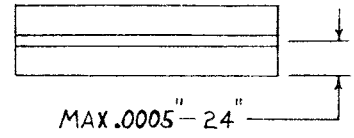

Fig. 27.78(b) Alignment tolerance of front surface to center T-slot of milling machine table.

When scraping is specified for this surface, proceed as follows:

OBJECTIVES: The Back Surface of the Table

1. To be square with the table top
2. To be parallel with the center T-slot
3. To have a surface quality of 5 - 25 bearing spots per square inch.

PROCEDURE:

The same tools and methods used to finish the front surface of the table are applicable here. Refer to Sec. 27.85.

Sec. 27.87
OBJECTIVES: The Flat Slides of the Table

1. To be parallel to the top surface of table.
2. To be fitted to the flat ways of the

saddle with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The flat slides are most conveniently situated for spotting and scraping if the table is inverted and placed on a work bench. For spotting these bearings we will be obliged to use two tools alternately, viz: the flat ways of the saddle employed as a template, and an ANGLE STRAIGHT EDGE.

After spotting paste has been applied to the flat ways of saddle, the member is placed on the table in the position shown in Fig. 27.79. Next the lightly oiled guiding way of the saddle is pushed in contact with the guided slide of the table. Then moving the saddle from end to end, the flat slides of table are spotted, except for a strip adjacent the gib slide of table and as wide as the inserted gib.

This strip of surface underlying the gib piece receives no wear. (A properly adjusted gib piece should not bear on the flat slides.) This is in marked contrast to the considerable abrasion affecting the remainder of the surface. After a period of use, the ridge of unworn metal may become very noticeable and must be removed to restore flatness. It can be spotted only by an ANGLE STRAIGHT EDGE as the front flat way of saddle is of inadequate width.

There is yet another reason for alternating these two spotting tools. This has to do with the short length of the saddle member in relation to the dimensions of the table. Due to this disparity, it is advisable to use an ANGLE STRAIGHT EDGE of equal or greater length than the table, so that a truly flat surface can be attained.

OBJECTIVE NO. 1 is satisfied by measuring the distance between the flat slides of the table and table top with a micrometer. Measurements are made at the four corners and at intermediate positions. If readings are identical, the flat slides are parallel to the table top.

OBJECTIVE NO. 2 is tested by observing the coloring of the markings transferred to the table slides by the saddle template and the ANGLE STRAIGHT EDGE. When the coloration and distribution of the markings are uniform on both slides, they are judged well fitted to the ways.

NOTE A point to watch particularly is the clearance between the table and the saddle at locations (X) and (X') shown in Fig. 27.79. To assure that the members do not rub, the Light Test must be satisfactorily executed before passing the member as acceptable. (Sec. 18.11) As an additional safeguard, inspect the grooves of both members for clearance.

Sec. 27.88

OBJECTIVES: The Guided Slide of the Table

1. To be parallel with the center T-slot.
2. To be fitted to the guiding way of the saddle with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE

The accuracy of the guided slide determines, to large measure, the performance of the table. By accuracy is meant not a short-lived condition, but one of some permanence based on a full length, surface bearing, area contact. Such a condition is realized only if the slope of the angular guided slide matches the slope of the angular guiding way of the saddle. Unless these slopes correspond, a line contact is formed on the surfaces inducing rapid wear on both.

To assure an area contact, the guided slide of the table should be spotted by and fitted to the guiding way of the sad-

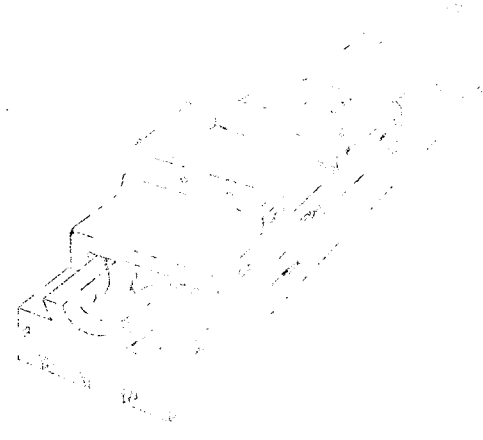

Fig. 27.[illegible] spotted by saddle [illegible]

dle. The first step in this operation consists of cleaning and oiling the flat slides and flat ways of both saddle and table components. A film of marking compound spread on the guiding way of the saddle prepares this member for use as a template. However, owing to the unequal length of the two members, a condition of flatness would be difficult, if not impossible, to achieve. It is advisable, therefore, to spot alternately with an ANGLE STRAIGHT EDGE of sufficient length.

Another good method is to construct a MALE DOVETAIL TEMPLATE employing as a pattern the female counterpart previously used for spotting the guiding way of the saddle. Possessing such a tool, the operator can dispense with much of the procedure mentioned above. It will be necessary to use the saddle member as a template only for the final finish spotting and that solely to assure the formation of an overall area contact. The ANGLE STRAIGHT EDGE should be again applied alternately with the MALE DOVETAIL TEMPLATE.

It is a good practice to test at frequent intervals for parallelism. This is a simple matter if the back of the table was scraped parallel to the center T-slot. The set up illustrated in Fig. 27.80 is appropriate if the back of the table is eligible as a check pint i.e. scraped and aligned. Under these circumstances, a suitable device will be a DIAL INDICATOR attached to a RIGHT ANGLE TEMPLATE as shown. The apparatus is moved from end to end of the flat slide keeping the contact point of the instrument against the angular guided slide of the table. Readings are taken at both extremities. If identical, they prove that the guided slide of the table is parallel to the center T-slot, thereby satisfying OBJECTIVE NO. 1.

Should the back of the table not have been scraped, a substitute technique will be required in order to accomplish proper alignment. The appropriate course is to bridge across the table dovetail and check for parallelism to the front of the table. This necessitates building an indicating jig, but since many suitable examples have been given previously, the mechanic should experience no difficulty on this score.

When the specifications of the job call for the maximum precision, the procedure described in Sec. 27.106 must be used. This is a static alignment test:

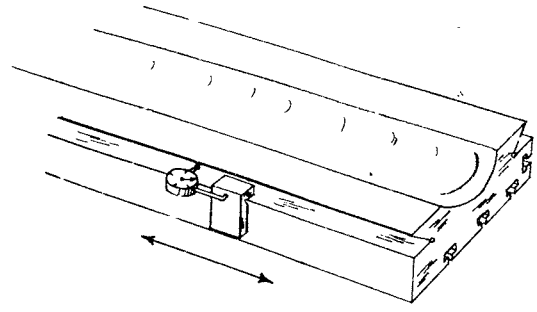

Fig. 27.80 Showing apparatus and method of testing alignment of guided slide to center T-slot by utilizing the finish scraped surface of back side of table as a check point.

"Center T-slot parallel with Table movement."

This test can be conducted now even though the table is not yet scrape-finished. To perform it the saddle is placed on the knee and the gib is inserted and adjusted for sliding tension. Next the table is positioned on the saddle with the guided slide held firmly by hand in contact with the guiding way of the saddle. A DIAL INDICATOR is attached to an arbor, and the button is set in contact with the table at the throat of the center T-slot. As the table is moved back and forth longitudinally, the reading is noted. If misalignment is evident, the member is removed, and scraping is resumed on the guided slide.

CAUTION: Prior to spotting, an inspection of the grooves should be made to prevent either the saddle member or the ANGLE STRAIGHT EDGE from bottoming.

Sec. 27.89

OBJECTIVES: The Gib Slide of the Table

1. To be parallel with the guided slide of the table.
2. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

As we mentioned previously, a flat gib piece is used on the gib slide of the table. Therefore, the operator can treat

this surface in either of two ways, viz:

1. Prepare the surface for a closely fitting flat gib. To do this, the slope of the angular gib slide of the table must be scraped so that it has the identical slope of the upper saddle gibbed surface. The proper technique in handling this situation is described in the following paragraphs titled, CASE ONE.
2. Make ready the surface for a loose fitting flat gib. This requires only that the angular gib slide be flat and parallel with the guided slide. Whatever random slope is generated on this surface, while scraping it flat, will be close enough. It is customary, however, to make the slope of the gib slide approximately equal to that of the guided slide. This method is described in CASE TWO.

Sec. 27.90
CASE ONE: Preparing the Gib Slide of Table for a

CLOSELY FITTING STRAIGHT FLAT GIB

PROCEDURE:

There are several possible methods of preparing a gib slide for association with a closely fitting straight flat gib. Where the construction of the members permits, the most simplified procedure is to spread marking compound on the upper gibbed surface of the saddle then effect transfer of the medium to the gib slide of table in the usual manner. This will help generate a slope on the gib slide of table identical to that of the gibbed surface of saddle. If the design of either member is such that these two surfaces cannot be brought into contact, then a TEMPLATE can be made up which will duplicate the essential slope.

As an alternative to a TEMPLATE, a vernier protractor can be employed periodically to measure the slope on the gib slide. Tests for OBJECTIVE NO. 1 calling for parallelism between the gib slide and the guided slide should be made frequently as the scraping progresses. The surface bearing quality required for OBJECTIVE NO. 2 must be achieved simultaneously.

To promote straightness and flatness the ANGLE STRAIGHT EDGE should be applied alternately with the test systems described above.

NOTE: Since straight flat gibs are, as a general rule, surface ground and not hand scraped, their production is exclusively a machine operation and hence will not be discussed. Dimensions of the flat gib piece are secured by appropriate measurements as discussed in Sec. 17.7.

Sec. 27.91
CASE TWO: Preparing the Gib Slide of Table for a

LOOSELY FITTING STRAIGHT FLAT GIB

PROCEDURE:

In preparing the gib slide for association with a loosely fitting flat gib, the principal requirement is parallelism with the guided slide of table.

A secondary consideration that is desirable, though not essential, is to match the slope of the upper gibbed surface of saddle. An ANGLE STRAIGHT EDGE should be applied to indicate the surface bearing quality.

The check for parallelism, in either Case One or Case Two above, is made with a set up similar to the one depicted in Fig. 27.81. (The permissible tolerance is indicated.)

After achieving the OBJECTIVES by any of the methods discussed, the parallelism of the gib slide is verified with the Sliding Member Test. To perform this test, the bearing surfaces are oiled, the saddle placed on the table, and the gib inserted and adjusted for sliding tension. Then the saddle is pushed by hand from end to end of the table. Any tendency towards looseness, or bind, should be noted.

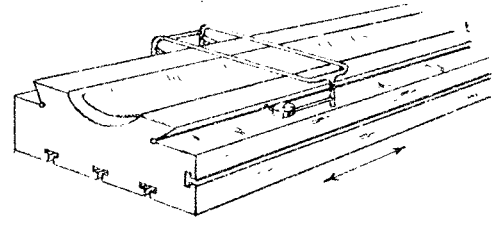

Fig. 27.81 Testing parallelism of gib slide of table to guided slide. Maximum tolerance .0005" in 24".

The indicated error is corrected by rescraping the gib slide of the table, Incidentally, this Sliding Member Test will also prove that the flat slides of the table are parallel to each other.

Sec. 27.92
OBJECTIVES: The End Surfaces of the Table

1. To be square with the flat slides and the guided slide of the table.
2. To have a surface quality of 4 - 5 bearing spots per square inch.

PROCEDURE:

The end of the table shown in Fig. 27.82 should be square with the flat slides and also the guided slide of the table. Otherwise, the table screw when attached may bind in the bearings located in the pads or brackets which will be fastened at each end of the table. This condition would be most noticeable when the table has reached its extreme limit of travel in either direction.

It is seldom necessary to shift these end surfaces very much, and the bearing quality provided is the minimum. Consequently, the operation can be performed expeditiously. A RIGHT ANGLE TEMPLATE, alternated with a STRAIGHT EDGE are the appropriate tools for spotting these surfaces. The TEMPLATE automatically forms the end surfaces square with the top of the table in one direction, and hence square also with the flat slides. A TOOL MAKER'S SQUARE held against the guided slide checks for OBJECTIVE NO. 1 in the other direction.

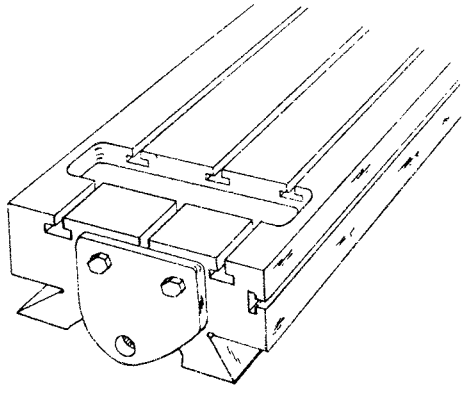

Fig. 27.82 Showing end pad fastened to table.

When both OBJECTIVES are effected, the table member is complete.

Sec. 27.93
Static Alignment Tests

We have now reached the stage where work previously completed should receive a final critical examination. Many preliminary checks have been conducted prior to this on each individual member of the Horizontal Milling Machine, as well as on the several sub-assemblies. If the OBJECTIVES have been satisfied in every case, then the machine, as a whole, is presumed to be accurate. Experienced mechanics, however, will wish to verify this assumption by a series of Static Alignment Tests. Essentially they are acceptance tests. If the tolerances are not exceeded, the machine tool is pronounced acceptable and assigned to production.

The alignment tests are scheduled in the approximate order in which the individual components were originally tested while scraping. Although performed previously during sub-assembly, they are repeated again, employing in some cases a modified set up. In executing others, an entirely different set up is devised to accomplish the same purpose.

To avoid repetition, and furthermore because the test diagrams are practically self-explanatory, the résumé of the procedure will be brief. For maximum benefit to the reader, the diagrams are accompanied by suggestions as to the probable source of error should tolerances be exceeded.

In order to duplicate working conditions as closely as possible, it is always good practice to run in the machine under power for about one hour before executing the tests. During this warming-up period, the various members are repeatedly inspected for quietness and smoothness of movement. When the machine attains a constant, normal, operating temperature the Final Static Alignment Tests may be performed.

Sec. 27.94
STATIC ALIGNMENT TEST NO. 1

Leveling the Horizontal Milling Machine

PROCEDURE:

The table top is tested for levelness. A PRECISION LEVEL is placed on the table top in two positions so as to test in both the longitudinal and transverse directions. Should the tolerance shown in Fig. 27.83 be exceeded, shims are driven under the base at the appropriate location until the table top assumes a level standing.

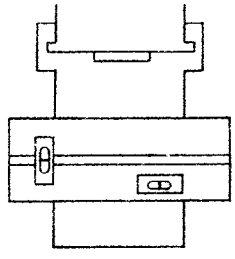

Fig. 27.83 Leveling table in longitudinal and transverse directions. Tolerance max. .0005" in 12".

Sec. 27.95
STATIC ALIGNMENT TEST NO. 2

Part 1 Spindle End Periphery Run Out.
Part 2 Spindle End Face Run Out.

PROCEDURE:

These tests should have been conducted before any treatment was given to the flat bearings. This matter was referred to in Sec. 27.5. All subsequent scraping and aligning operations have been based on the premise that these conditions were satisfied at that time. If this has not been the case, and these tests are only now being made it is highly probable that all members and surfaces are misaligned to some degree if any error in excess of the tolerance shown in Fig. 27.84a and Fig. 27.84b is detected.

Sec. 27.96
STATIC ALIGNMENT TEST NO. 3

Spindle Run Out

PROCEDURE:

In repeating this test now we are only verifying a fact that should have been established preparatory to working on the bearing surfaces. If the error exceeds the tolerance shown in Fig. 27.85, major revisions of all planes will undoubtedly be necessary. For complete details describing the procedure refer to Sec. 27.4.

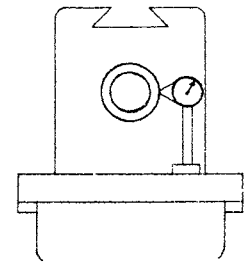

Fig. 27.84(a) Spindle End Periphery run out. Tolerance max. .0002".

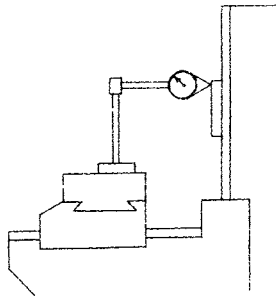

Fig. 27.84(b) Spindle end face run out. Tolerance max. .0002".

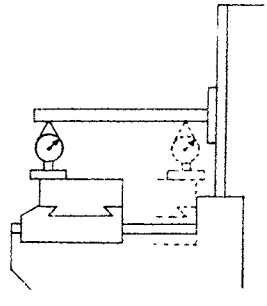

Fig. 27.85 Spindle run out. Tolerance max. at 1 1/4" from spindle .0005" ; at 18" from spindle .001".

Sec. 27.97
STATIC ALIGNMENT TEST NO. 4

Movement of the Knee, Saddle, and Table when the clamp of each is locked.

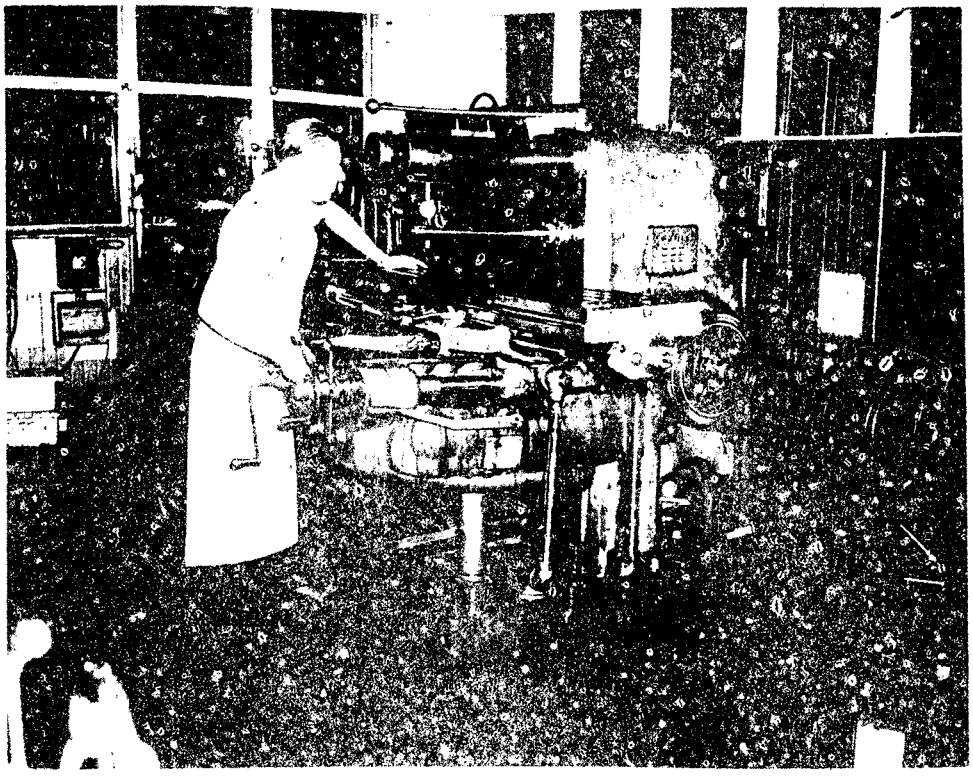

PLATE 50. Checking spindle run out of horizontal milling machine. (Courtesy - Kearney & Trecker Corp.)

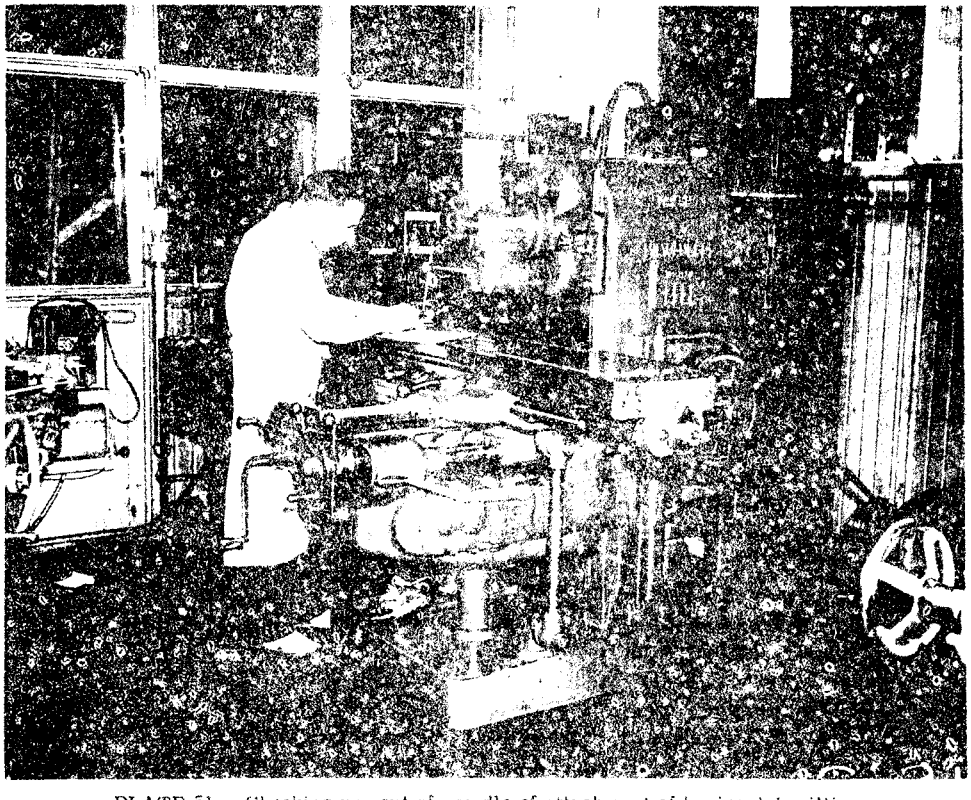

PLATE 51 Checking run out of spindle of attachment of horizontal milling machine. (Courtesy - Kearney & Trecker Corp.)

PROCEDURE:

The three components are tested consecutively. If the tolerance represented in Fig. 27.86 is exceeded on any or all of them, the error probably will be located in one or more of the following sources, viz:

1. The gib piece of the particular member is not adjusted properly. The probability is that it is too loose. See Sec. 17.36 Sliding Pressure.
2. Convexity may be indicated in one or more of the ways or slides. This can be corrected only by scraping the affected surfaces. Proper handling of the spotting tool at the appropriate time would have disclosed this condition. The application of the Shake Test as each member was undergoing the Sliding Member Test would also have aided in its detection. Refer to Sec. 22.5 Shake Test.
3. The tapered gib pieces provided for the knee and the saddle may not have been scraped to the proper taper.

Sec. 27.98
STATIC ALIGNMENT TEST NO. 5

Vertical Movement of Knee Parallel with the Column Face.

PROCEDURE:

When the tolerance shown in Fig. 27.87 is exceeded it could indicate a lack of parallelism between the face of the column and the gib bracket ways. The existence of such a condition allows the knee to slack away from the column face or causes it to be drawn inward towards the column. If there is evidence of this, the machine must be disassembled and the column ways tested for parallelism. This deficiency would not be apparent now if the Sliding Member Test had been applied as the knee was nearing completion. Refer to Sec. 27.32.

A secondary source of error may be in the elevating screw and the gearing associated with the elevating hand wheel. If these units are not accurately machined, or incorrectly assembled, excessive pressure may be required to elevate the knee. This may force the knee towards or away from the column causing the tolerance to be exceeded. These auxiliary parts should be examined before dismantling the machine, particularly if the operator is convinced he has done a conscientious scraping job.

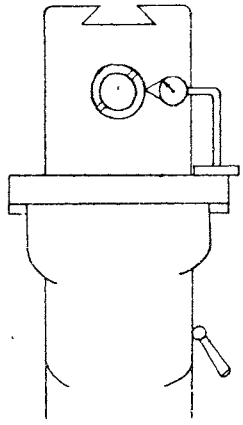

Fig. 27.86 Movement when knee, saddle, and table clamps are locked. Tolerance for each max. .001".

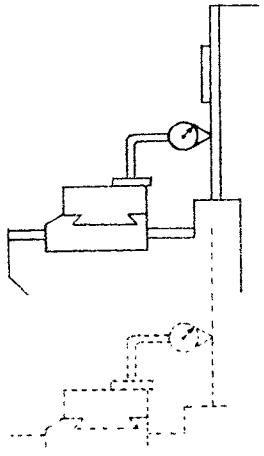

Fig. 27.87 Vertical movement of knee parallel with column face. Tolerance max. .001" in 18".

Sec. 27.99
STATIC ALIGNMENT TEST NO. 6

Table Top Square with Vertical Movement of Knee.

PROCEDURE:

This test is conducted with the following set up. A DIAL INDICATOR is attached to a stub arbor inserted in the tapered spindle hole. By turning the elevating hand wheel one or two complete turns, the knee is raised from its lowest position thereby removing all slack from the elevating mechanism. Then a MASTER SQAURE is set upright on the table in a position square with the column face and in contact with the button of the instrument. The knee is cranked upward as far as possible, and any change in the DIAL

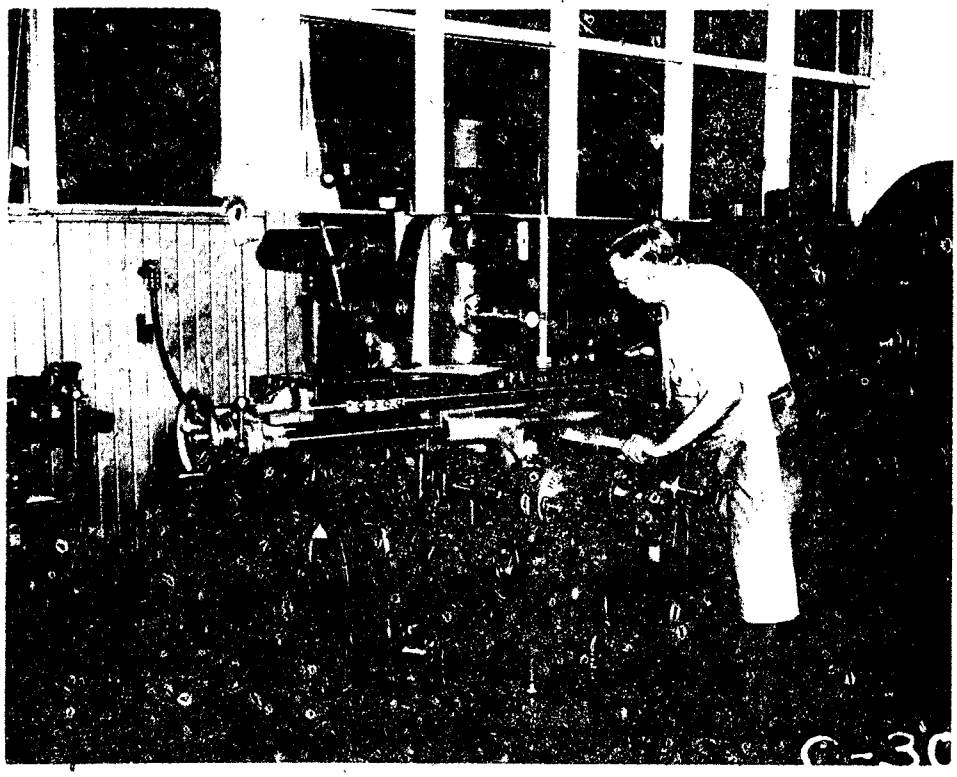

PLATE 52. Checking table top for squareness with guiding way of column utilizing vertical movement of knee of horizontal milling machine. Note the scraped triangle clamped to the table top. (Courtesy - Kearney & Trecker Corp.)

reading is noted.

If the tolerance given in Fig. 27.88 is exceeded, the fault will be located in one or more of three possible sources, namely:

1. The flat way of the knee may be misaligned with the guiding way of the column.
2. The flat slide of the saddle may not be parallel with the flat ways of the saddle.
3. The flat slides of table may not be parallel with top of table.

To ascertain the source of error more definitely, a series of tests must be undertaken. In brief, they are as follows in the order in which the errors noted above are listed.

1. After the table and saddle are removed, the alignment of the flat way of knee to the guiding way of column is checked utilizing the procedure discussed in Sec. 27.35. If a misalignment is indicated, the flat way of the knee must be rescraped. This alters the parallelism of the gib bracket ways of the knee, in the transverse direction. Consequently, these

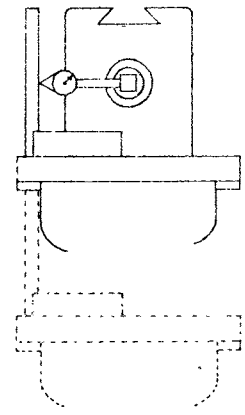

Fig. 27.88 Table top square with vertical movement of knee (in a plane parallel with column). Tolerance max. .001" in 18".

surfaces must be reoriented by scraping them parallel with the flat way of knee. The guiding way and gib way of this member must also be rescraped so that they are square with the flat way. In addition, the gib bracket bearings of the saddle and all the lower bearing surfaces of the saddle must be realigned, and the gib piece refitted to match the new conditions originating in the rescraping of the knee ways. Thus it can be seen that extensive reworking involving several surfaces would be required if a misalignment of the flat ways of knee to guiding way of column were discovered at this time. (See Note)

2. On the other hand, if the flat ways of the knee are within the tolerance, suspicion falls on the flat slides of saddle. Tests specified in Sec. 27.52 will indicate if this doubt is justified.
3. If the preceding test shows that both the flat slides and flat ways of the saddle are correctly aligned, it leaves as a final possibility the slides of the table. The parallelism of the slides of table to the top of table can be verified without removing the member by conducting STATIC ALIGNMENT TEST NO. 7 described in Sec. 27.100.

It can thus be seen that by a process of elimination, the error will be located in one of the foregoing steps.

NOTE: STATIC ALIGNMENT TESTS NO. 6 and NO. 8 are usually performed in succession so that if misalignment is apparent all corrective work on the knee flat way can be performed at the same time.

Sec. 27.100
STATIC ALIGNMENT TEST NO. 7

Rise and Fall of Table in Longitudinal Movement

PROCEDURE:

After an arbor is inserted into the spindle hole, a DIAL INDICATOR is fastened to it and adjusted so that the button is in contact with the top of the table. The average reading is noted as the table is moved back and forth under the button of the instrument.

Should the tolerance given in Fig. 27.89 be exceeded it indicates that the flat slides of table are not parallel with respect to the top of table, measured in the longitudinal direction. The error is corrected by scraping the flat slides of table as described in Sec. 27.87.

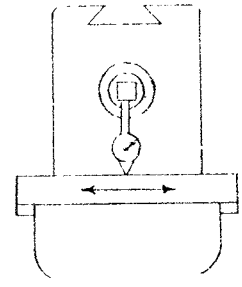

Fig. 27.89 Rise and fall of table in longitudinal movement. Tolerance max. .001" in 24".

Sec. 27.101
STATIC ALIGNMENT TEST NO. 8 (part 1)

Cross Movement of Saddle Parallel with Spindle in Vertical Plane

PROCEDURE:

The first step is to insert the test bar in the spindle and perform a run out test. When the mean position of eccentricity error of the test bar is determined, it is stationed at the vertical diameter. Mounting a DIAL INDICATOR on the top of table, the button is placed in contact with the test bar at the vertical diameter. The cross-movement of the saddle is employed to move the instrument along the bar.

Should the reading on the instrument

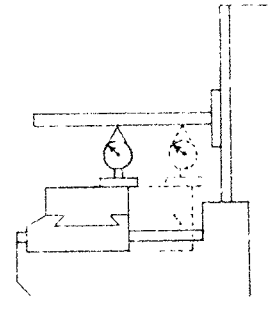

Fig. 27.90(a) Cross movement parallel with spindle in vertical plane. Tolerance max. .001" in 12". (Low point at rear)

disclose that the unilateral tolerance specified in Fig. 27.90a has been exceeded, the misalignment is caused by the flat ways of the knee not being square with the column face. This can be proved by removing the table and saddle and conducting tests suggested in Sec. 27.35.

To rectify the vertical misalignment it will be necessary to rescrape the flat way of the knee. This, however, affects the alignment of the gib bracket ways which also must be rescraped to maintain parallelism, vertically, with the flat way of knee. In addition, the bracket bearings of saddle must be rescraped to compensate for the reduced distance between the flat way and the gib bracket ways of knee. Thus it can be seen that when the initial alignment on the individual member was not correctly performed, a whole series of operations must be done over.

Sec. 27.102
STATIC ALIGNMENT TEST NO. 8 (part 2)

Cross Movement of Saddle Parallel with Spindle in Horizontal Plane

PROCEDURE:

Next the mean position of eccentricity error of the test bar is turned to the horizontal diameter and the button of the DIAL is placed in contact thereon. The cross-movement of the saddle is utilized to pass the button of the instrument along the test bar.

If there is a misalignment in excess of the tolerance shown in Fig. 27.90b, it is caused by the guiding way of knee not being square with column face. To prove this the table and saddle are removed, and the tests discussed in Sec. 27.35 are applied.

Correction of the error in the horizontal plane is made by rescraping the guiding way of the knee. This in turn necessitates rescraping the gib way of the same member. Since the effect of such modification is cumulative, it will also require alteration of the gib piece.

Sec. 27.103
STATIC ALIGNMENT TEST NO. 9

Parallelism of Over Arm with Spindle in Vertical and Horizontal Planes

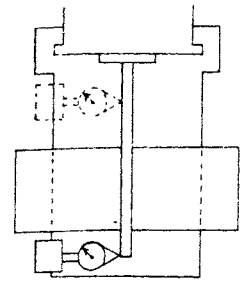

Fig. 27.90(b) Cross movement parallel with spindle in horizontal plane. Tolerance max. .001" in 12".

PROCEDURE:

After the test bar is inserted into the tapered hole in the spindle, a run out test is conducted to determine if it is aligned with the spindle. This test also locates the mean position of eccentricity error on the bar.

Next a DIAL INDICATOR is suitably attached to the over arm member, which is then adjusted for sliding pressure. With the contact button of the instrument on the vertical diameter of the test bar, the over arm is run in and out. This is repeated on the horizontal diameter. The test bar is turned so that the mean position is utilized in both planes successively.

If the tolerance given in Fig. 27.91 is exceeded in the vertical plane, the flat ways of the over arm support must be rescraped to correct the misalignment. This error should have been noted during the scraping and aligning procedure outlined in Sec. 27.37.

When the misalignment in the horizontal plane exceeds the tolerance, same figure, it will be necessary to rescrape

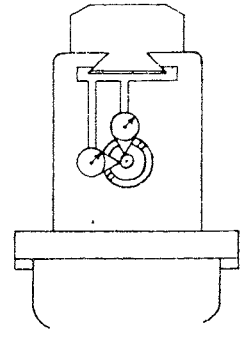

Fig. 27.91 Parallelism of over arm member with respect to spindle in vertical and horizontal plane. Tolerance for both planes max. .001" in 18".

the guiding way of the over arm support. The procedure covering this surface is specified in Sec. 27.38.

The gibbed surface may also require treatment to achieve parallelism with the guiding way.

Sec. 27.104
STATIC ALIGNMENT TEST NO. 10

Alignment of the Arbor Supports with the Spindle

PROCEDURE:

A test bar is inserted into the bore of the arbor support. This is followed by introducing a stub arbor into the tapered hole of the spindle and attaching a DIAL INDICATOR to it. The swing round method, discussed in Sec. 16.4, is applied. If the tolerance represented in Fig. 27.92 is exceeded, then the bearing surfaces of the arbor support must be again scraped to correct the misalignment. This procedure is outlined in Sec. 27.45.

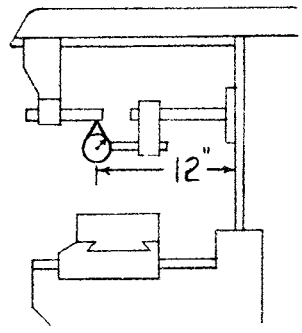

Fig. 27.92 Alignment of arbor support with spindle. Tolerance max. run out .001".

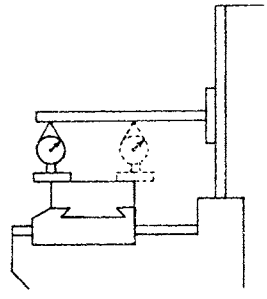

Fig. 27.93 Table top parallel with spindle. Tolerance max. .001" in 12". (Low point at rear)

Sec. 27.105
STATIC ALIGNMENT TEST NO. 11

Table Top Parallel with the Spindle

PROCEDURE:

The test bar is introduced into the spindle hole and tested for run out. If true, the bar is revolved to place the mean position of eccentricity error at the vertical diameter. Next a DIAL INDICATOR attached to a Surface Gage is set at the front of the table top. The button of the instrument is placed in contact with the bar at the vertical diameter. As the device is moved by hand back and forth under the test bar, the maximum deflection is noted. This is repeated with the gage at the back of the table.

If the unilateral tolerance, represented in Fig. 27.93, is exceeded, then the error may be traced to one or more of three conditions, viz:

1. The flat way of the knee is not aligned to the column face. The procedure outlined in Sec. 27.35 should be rechecked.
2. The upper ways of saddle and lower slides of saddle are not parallel as measured in the transverse direction. The procedure described in Sec. 27.52 should be gone over again.
3. The flat slides of table are not parallel with the top of table as measured in the transverse direction. The procedure given in Sec. 27.87 should be repeated.

When the source of the misalignment is located, it is eliminated by scraping the appropriate surfaces.

Sec. 27.106
STATIC ALIGNMENT TEST NO. 12

Center T-slot parallel with the Table Movement (top view)

PROCEDURE:

An arbor is inserted into the spindle hole. After attaching a DIAL INDICATOR to the arbor, the button of the instrument is positioned against the throat of the T-slot. As the table is moved longitudinally any variation in the reading is noted. Then the button is transferred to the other side of T-slot where the procedure

is repeated. Thus both sides of the T-slot will be tested.

If the tolerance given in Fig. 27.94 is exceeded, it signifies that the guided slide of the table is not parallel with the center T-slot and hence must be re-scraped. This action necessitates re-working the gib slide of the table until it too is parallel. The procedures relating to these bearing surfaces are treated in Sec. 27.88 and Sec. 27.89 respectively.

Sec. 27.107
STATIC ALIGNMENT TEST NO. 13

Center T-slot Square with Spindle (top view) Standard Saddle

PROCEDURE:

Center the table. Then press two ground PARALLELS into the center T-slot at points equi-distant from the mid-point of the table. After inserting the arbor into the spindle hole, a DIAL INDICATOR with attached arm is fastened to it. The swing round method is utilized to obtain a DIAL reading against each ground PARALLEL in turn.

If the tolerance shown in Fig. 27.95 is exceeded, the guided slide of the saddle needs to be rescraped to correct this misalignment. As a consequence, the tapered gib of the saddle may require alteration to match the new taper which will now exist between the gib way of knee and the lower gibbed surface of saddle. The procedure relating to this surface is discussed in Sec. 27.53.

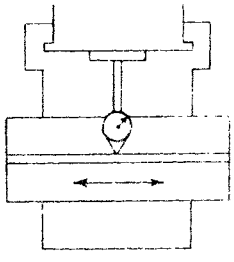

Fig. 27.94 Center T-slot parallel with table movement. Tolerance max. .001" in 18".

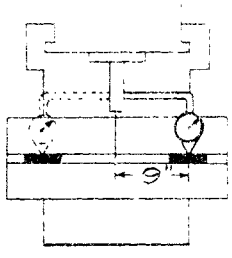

Fig. 27.95 Center T-slot square with spindle. Tolerance max. .001" in 18".

Sec. 27.108
STATIC ALIGNMENT TEST NO. 14

T-slots square with Top of Table

PROCEDURE:

Fig. 27.96 is self-explanatory and requires no description. Tolerance max. .001" per inch.

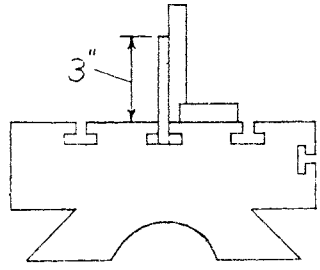

Fig. 27.96 T-slots square with top of table. Tolerance max. .001" in 3". The drawing is self-explanatory.

Sec. 27.109
STATIC ALIGNMENT TEST NO. 15

Fig. 27.97(a) Back lash in lead screws read on dials.

	Tolerance max.
Table screw	.005"
Cross screw	.005"
Vertical screw	.008"

Fig. 27.97(b) Maximum error in total length.

	per foot	in total length
Table screw	(±) .001"	(+) .001" (-) .002"
Cross screw	(±) .001"	(+) .001" (-) .002"
Vertical screw	(±) .001"	(+) .001" (-) .002"

Sec. 27.110
STATIC ALIGNMENT TEST NO. 16

(For Universal Saddle)

Axis of Pivot Offset with respect to Axis of Spindle.

PROCEDURE:

A test bar is inserted in the spindle, given a run out test and turned to place the mean position of eccentricity error in the horizontal plane. The table is moved longitudinally until one end is flush with the end of the saddle. The universal saddle-table assembly is now adjusted transversely on the knee to locate the axis of the pivot approximately under the free end of the test bar. A DIAL INDICATOR is rigidly positioned on the table top with the plunger adjusted to touch the free end of the test bar at the horizontal diameter.

The table is swiveled 180° thus placing the plunger of the instrument against the test bar on the opposite side. The difference between the two readings indicates the amount of offset of the axis of the pivot with the axis of the spindle. The tolerance allowed is shown in Fig. 27.98. If the tolerance is exceeded, the reason may be found outlined in Sec. 27.80.

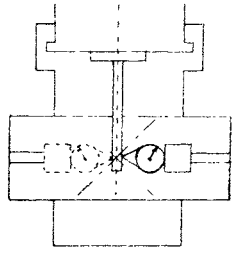

Fig. 27.98 Axis of pivot offset with respect to axis of spindle. Tolerance max. .002".

Sec. 27.111
STATIC ALIGNMENT TEST NO. 17

(For Universal Saddle)

Center T-slot offset with respect to Axis of Pivot.

PROCEDURE:

A test bar is inserted in the spindle, a run out test conducted, and the bar turned to place the mean position of eccentricity error in the horizontal plane.

The saddle-table assembly is swiveled so that the center T-slot is parallel with the axis of the spindle.

A DIAL INDICATOR is attached to a jig. The jig is placed in the center T-slot against one side of the T-slot throat. When this is accomplished, the plunger of the instrument is adjusted to touch the test bar at the horizontal diameter, and a reading is taken.

The DIAL INDICATOR and jig are transferred intact to the other side of the throat of the center T-slot. The reading is noted. The difference in readings denotes the amount of offset of the center T-slot with respect to the axis of the pivot.

The tolerance allowed is indicated in Fig. 27.99. If the tolerance is exceeded, the reason may be found by reference to Sec. 27.81.

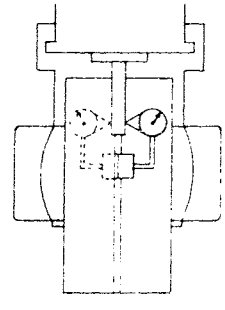

Fig. 27.99 Center T-slot offset with respect to axis of pivot. Tolerance max. .002".

Chapter 28

THE VERTICAL MILLING MACHINE

The vertical milling machine falls into two principal classifications, viz:

1. The Sliding Head Vertical Miller, wherein the head is adjustable in a vertical direction while the axis of the spindle remains in a vertical plane.
2. The Swivel Head Vertical Miller, wherein the head is held at a fixed height but is free to swivel, thereby allowing the axis of the spindle to be in any plane between vertical and horizontal.

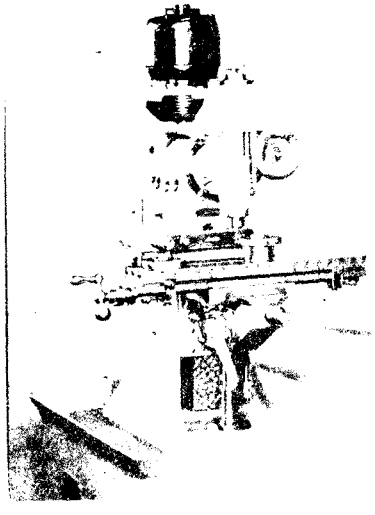

PLATE 53. Vertical milling machine with swivel head. (Courtesy - Elgin Tool Works.)

In the following pages a vertical milling machine utilizing the Sliding Head will be discussed. Fig. 28.1 shows such a machine completely assembled. This familiar machine tool has many points of similarity to a horizontal miller but it also has other distinctive features which are peculiar to it alone, and therefore of special interest to the scraping operator. For this reason, a detailed description of the problem and the procedure involved in reconditioning the Vertical Miller is justified.

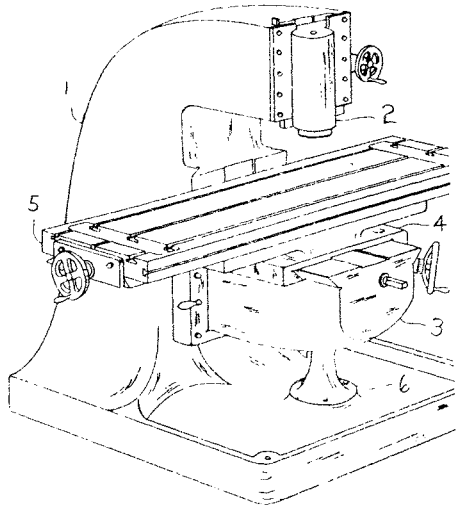

Fig. 28.1 Assembled Vertical Milling Machine showing principal parts.

(1) column (2) sliding head (3) knee (4) saddle (5) table (6) pedestal and boss

Sec. 28.1
The Sliding Head Vertical Milling Machine

The sliding head vertical miller described and illustrated in this chapter, combines the structural design found on popular models of several manufacturers. One notable difference between the elementary form shown in Fig. 28.1 and the one illustrating the horizontal miller in Fig. 27.1 will be readily apparent. This machine utilizes dovetails on most of the principal members, whereas the example demonstrating the horizontal miller consists mainly of square edges. As a result, scraping methods vary as between machines, although the alignment tests, and the requirements thereof, are somewhat similar. The reason for varying the type of bearing surface is to provide information in treating a variety of bearing surfaces.

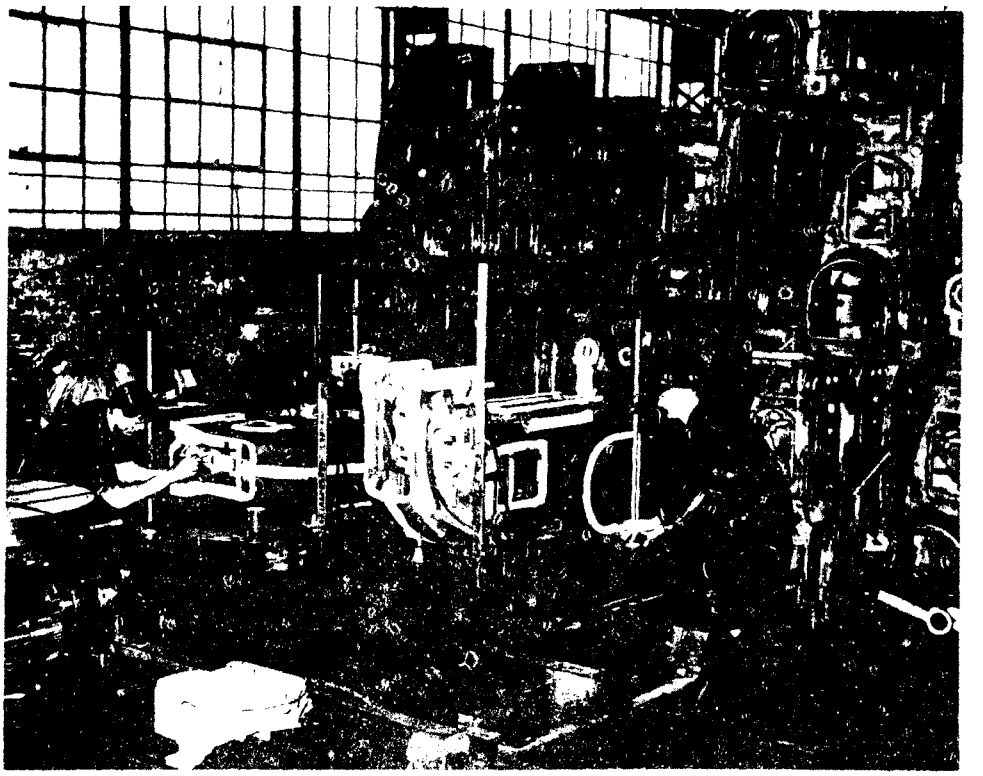

PLATE 54. Laying out a column casting of a vertical milling machine preliminary to machining. Note the care shown in laying out each surface to be machined. (Courtesy - Kearney & Trecker Corp.)

Sec. 28.2
Components

The various members of the Vertical Milling Machine of interest to the scraping operator are enumerated and described as follows:

1. The Column: The massive casting supporting the combined weight of the other machine members, in addition to the work piece, is known as the column, or frame. This member has two groups of bearing surfaces, viz: the lower group, or column ways, that guide the knee; the upper group, or head support ways, that guide the sliding head.
2. The Sliding Head: This member is guided vertically by the ways of the head support located at the top of the column. The sliding head encloses the spindle.
3. The Knee: The component, guided by the ways of the column and vertically adjustable, is called the knee. It supports the saddle and table assembly.
4. The Plain Saddle: The lower bearing surfaces of this member are guided in cross-movement by the ways of the knee. The upper bearing surfaces guide the table in longitudinal movement.
5. The Table: The top surface of this member is provided with T-slots. This feature permits the work piece and also various attachments, such as the vise, the dividing head etc., to be secured by means of bolts.

The several members of the Sliding Head Vertical Milling Machine will be discussed in the order enumerated above. This is also the logical sequence of scraping operations.

Sec. 28.3
The Column

For purposes of convenience and clarity the bearing surfaces of the column are

divided into two groups, as follows:

GROUP NO. 1 The surfaces associated with the knee member comprising the column ways, viz:

1. The face of the column
2. The angular guiding way of column
3. The angular gib way of column

GROUP NO. 2 The surfaces associated with the sliding head, including:

4. The flat ways of the head support
5. The guiding way of head support
6. The gibbed surface of head support
7. The gib bracket bearings of head support.

The surfaces listed in GROUP NO. 1 should be scraped first and in the order enumerated.

Sec. 28.4
Selecting the Datum Point

The first problem in rescraping a Sliding Head Vertical Milling Machine is the selection of a Datum Point. For this type of machine tool the choice will necessarily be a flat bearing surface because there is no immovable, rotating member conveniently accessible, as in the case of the spindle of the Horizontal Milling Machine. Of the several available flat bearing surfaces, the face of the column, shown in Fig. 28.2, is most appropriate for the following reasons:

1. It is the largest scraped surface on the member. Consequently, it is easier to align smaller surfaces to it, than vice versa. This is a convincing reason because it means a considerable saving of time and effort. In other words, when adjustments are required it is preferable to make them on smaller surfaces.
2. More than any other surface, the column face is the most convenient one against which to directly check the other members.

Sec. 28.5
Dismantling

The initial operation on the Vertical Miller consists in stripping the machine

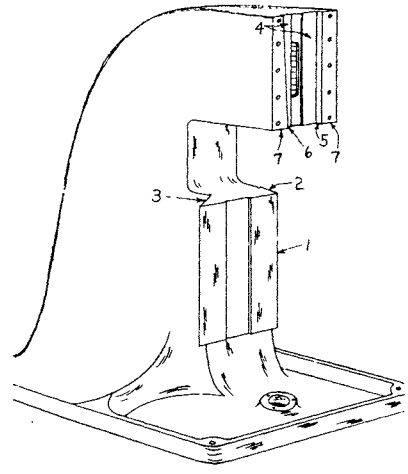

Fig. 28.2 Column of vertical milling machine showing principal bearing surfaces.

(1) face (2) angular guiding way (3) angular gib way (4) flat ways of head support (5) guiding way of head support (6) gibbed surface of head support (7) gib bracket bearings of head support.

of all components including, gearing, shafting, bearings, etc., and examining each part carefully. Defective parts are assigned to the machine shop department where repair work is immediately started, so that they will be ready when needed.

Usually the specifications accompanying the order will be based upon the findings of the Exploratory Examination of the column, and to a lesser degree, of the other members. The disposition of the gearing etc., can, however, wait upon the completion of the column face. In fact it is often desirable to do so because the requirements can then be determined with greater accuracy. At the risk of being repetitious, it deserves to be emphasized that any modification of existing alignments must be performed on the auxiliary parts, since it would be illogical to shift the Datum Plane.

Sec. 28.6
Preparations for Exploratory Examination

After the milling machine has been dismantled, the column is cleaned of all dirt and grease. The casting is then tipped over on its back, face uppermost, as shown in Fig. 28.3. In this position we have the best opportunity to conduct an Exploratory Examination of the face of the column.

Having selected the face of the column

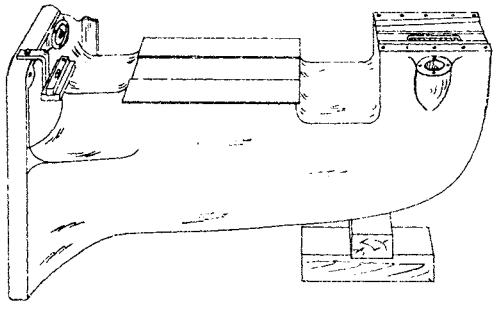

Fig. 28.3 View of column positioned horizontally, face uppermost. Wood blocks are used to support one end. A check point is shown bolted to the base.

as the Datum Point, we are confronted with the unpleasant fact that this surface often is in poor condition. It may be badly worn and, in some few cases, it may be warped. Obviously, in such a situation the surface must be restored to good condition before other surfaces can be aligned to it. However, it is not enough merely to produce flatness and good surface bearing quality. Although these characteristics are essential and must be developed, the operation is not a success unless it is accomplished in such a way that the resulting surface is parallel to the plane of the original factory-new surface. If this is not done, considerable extra work is required to re-align gearing and shafting to the newly imposed conditions. Furthermore, failure to re-produce, or closely approximate, the Datum Point in a plane parallel to the original factory-new surface has a cumulatively adverse effect on many of the other surfaces and members of the milling machine. The reasons for this and a few horrible examples are detailed in Sec. 23.20 Preserving the Original Plane.

Sec. 28.7
Exploratory Examination

The principal purpose of our survey of this member is to locate the plane of the original factory surface. Other pertinent facts, while valuable, are not of primary importance. Indications of warping due to abuse or ageing; convex conditions caused by wear; scratches, dents, and other defects; all are searched for by the operator as a matter of course, although they are of secondary interest. Other members of this machine are also given an equally thorough inspection because it is good practice to do so, but on the column it is a vital, indispensable operation.

A number of possible methods useful in finding the original factory plane, and in producing a new surface parallel to it, are discussed in the following pages. Since each of these is characterized by certain restrictions and advantages, it will be left to the operator to decide which one of them is appropriate to his specific case.

The reason that this subject is so exhaustively covered is that the column face is usually quite badly worn. This multiplies by several times the difficulties that beset an operator in scraping it parallel with the plane of the original factory-new surface.

Sec. 28.8
METHOD NO. 1 Scraping "Straight Down"

PROCEDURE:

Perhaps the easiest method to pursue is as follows: The column face is examined for areas which show the least degree of wear. To facilitate this inspection, the surface is spotted to make these portions more distinguishable. As additional measures the Pivot Test (Sec. 22.3) and the X Test (Sec. 22.2) are applied to detect convexity. Tests for "wind" discussed in Sec. 22.6 should be made also.

The information thus obtained is analyzed to determine, in so far as possible, the plane of the original factory surface. Then the scraping operation is conducted so as to produce a surface as nearly parallel to that plane as is consistent with the operator's skill as a scraper and his ability to correlate the results of the spotting tests.

Sec. 28.9
METHOD NO. 2 Using the Horizon as the Datum Line

PROCEDURE:

If there remains a portion of the original surface recognizable by clear, sharply

defined, scraping or frosting marks, a PRECISION LEVEL may be placed thereon and the face of the column leveled. The casting is shimmed as required, and then solidly blocked. As the scraping proceeds, frequent tests should be made to observe the degree of levelness. Achieving this condition signifies that the surface is being kept parallel to the plane of the factory-new surface.

The success of this method depends on solid blocking of the member to prevent shifting under the pressure of the scraping cuts. It is also advisable to establish an independent check point from which to re-level the column face should the member be accidentally dislodged in the course of scraping operations. Remember, during this reconditioning work the entire surface is altered by the removal of metal. Consequently, it is desirable to have an independent check point that will not be affected, even indirectly, by the scraping process nor by any shifting of the column caused thereby.

Since blocking is so essential to good results with this method, this subject will be amplified.

Sec. 28.10
Blocking to Prevent Shifting

After leveling the column, which is a required operation if Method No. 2 is adopted, it should be solidly blocked to prevent any movement, or shifting, due to pressures induced by spotting or scraping the face. A fuller understanding of the importance of dependable blocking might be had by a brief explanation of the serious effects resulting from failure to do so. For example:

The leveling operation is always performed from the least worn part of the column face. This area, being higher, must necessarily be scraped more heavily to reduce it to the level of the more seriously deteriorated portion. In other words, it will have the greatest amount of metal removed. After just one scraping cycle this relatively flat, original surface will be obliterated. Thereafter, should the column slip, as the blocks shoring up the end of the casting change position, the operator would have to re-level it, if he expected to continue using this method in checking the work surface for tilt. Of course, the operator could re-level the casting in some haphazard plane, but there would be no assurance that it had been restored to the original position. Thus it would not be known for certain that the surface was being scraped parallel to the original factory surface.

If the operator is careful to scrape the surface "straight down" at all times, as good scraping practice recommends, he could re-level the column by laying the instrument on the newly scraped surfaces. It is possible that such re-leveling could be performed so closely there would be no serious error. This presupposes that the dislocations occurred as a sudden movement of the column and was pronounced enough to be instantly noticeable.

The greater danger would lie in an imperceptible, creeping movement of the column due to poor and inadequate blocking. If the operator is unaware of what is taking place, repeated checks with the PRECISION LEVEL, to determine if the surface is being scraped parallel to the original surface, appear only to indicate that efforts to scrape "straight down" are not succeeding. If the dislodgment of the casting continues at a constant rate, it is not long before the operator begins to realize that something is wrong and takes steps to correct it.

However, the greatest harm occurs if the shifting is checked spontaneously before the operator is aware that it has ever begun. Then the operator, totally oblivious to what has happened, will test with the LEVEL and will scrape the column face to a plane which is not parallel to the original factory surface. How serious will be the effects of this on the alignments and fittings of other members, depends entirely upon the extent of the displacement.

It would seem that some preventive measure is essential to avert this possibility. Therefore, an auxiliary check point of some kind is called for.

Sec. 28.11
The Check Point

In spite of all reasonable precautions, the column member may shift during the spotting and scraping processes. To guard against this happening it is standard practice among experienced operators to

provide themselves with a check point. This is a simple and convenient means of detecting any movement should it occur. It also facilitates re-leveling the column face to the original position. It does not take much time to prepare such a device, and it is always a wise thing to do.

A check point may be a portion of the machine, such as a bearing surface not immediately affected by current scraping operations. Necessarily, it must check level when the face of the column is leveled. Since this condition is not easily satisfied it is customary to utilize another kind of check point in the form of a small metal plate which is scraped or ground flat on one side and bolted to the base or some other handy location. It is attached after the face of the column is satisfactorily leveled and before any scraping is attempted. This plate must also be leveled in both directions, before locking it in position. Fig. 28.3 shows such a check point bolted to the column.

A PRECISION LEVEL can be placed on it from time to time for spot checks to learn whether the column has slipped due to scraping pressures. By using the check point, the operator can properly readjust the column, if and when necessary, and then resume scraping.

Sec. 28.12

METHOD NO. 3 Utilizing Adjacent Surfaces

PROCEDURE:

If the column face is so badly worn that no trace of the original factory surface remains, it is still possible to arrive at a close approximation of the original plane in the transverse direction by utilizing the relationship of adjacent surfaces and making certain deductions therefrom.

For example in Fig. 28.4, the column member is provided with dovetails. Consequently, the relationship of the face to adjacent surfaces would most probably be some standard angle. In such a case proceed as follows:

A SCRAPED PARALLEL is placed cross-wise on the column face, as in Fig. 28.4. Then a Vernier Protractor adjusted to the standard angle is placed against an adjacent surface with the blade extending inwardly over the top of the PARALLEL.

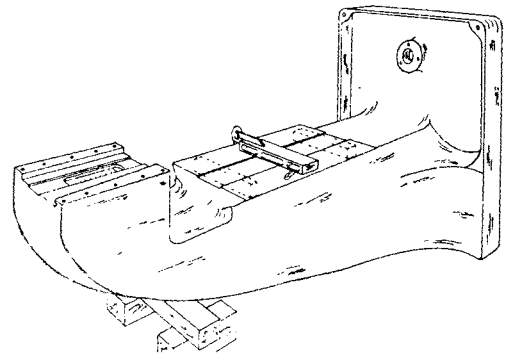

Fig. 28.4 Showing method of estimating the plane of the original factory-new face of column utilizing adjacent dovetail surfaces for check points.

The PARALLEL is shimmed so that it is approximately parallel to the blade. Next the Protractor is moved around to the other side and the routine is repeated from the opposite dovetail surface. This procedure adjusts the top of the PARALLEL to approximately the same angle with respect to both dovetail surfaces. To obtain an average, overall picture of the column face and adjacent surfaces, other PARALLELS are placed nearby, as shown by the dotted lines, and the procedure is repeated. The several PARALLELS may be of assorted sizes or thicknesses.

Next a PRECISION LEVEL is laid on each PARALLEL in turn. The average resultant of these readings is now taken as a guide and the face of the column is leveled to this standard.

To assure that this plane will not be displaced when scraping begins, it is advisable to block the casting solidly to prevent shifting. Other procedures equally essential to the successful utilization of the method were outlined previously in Sec. 28.9.

The reliability of this method is dependent on the condition of the dovetails. (The truer these surfaces the more effective the tests.) One shortcoming of the method is that it provides no information indicating the plane in the longitudinal direction.

Sec. 28.13

METHOD NO. 4 Utilizing the Sliding Head Movement

PROCEDURE:

We can determine the plane of the

original factory surface in the longitudinal direction by proceeding as follows:

The sliding head is mounted on the column. An arbor is inserted into the tapered hole of the spindle. Next a DIAL INDICATOR is fastened as shown in Fig. 28.5. The normal "in and out" movement of the head is short, viz: 4 to 8 inches, but this may be increased if the feed screw is removed. Small as this action might be, it is still sufficient to provide an indication of the scraping trend in the longitudinal direction. The DIAL reading will assist in deciding if the column face is approximately parallel to the plane of the original factory surface.

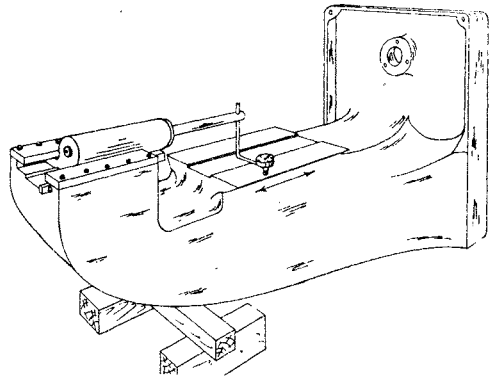

Fig. 28.5 Using movement of sliding head to determine if face is approximately parallel to plane of original factory surface.

An alternative procedure would be to insert a test bar into the tapered hole of the spindle. A run out check is conducted, then the bar is revolved so that the mean position of eccentricity error is at the vertical diameter. Occasional tests are made with a DIAL INDICATOR from the column face to the test bar to determine the scraping trend.

The value of these procedures depends on the accuracy of the sliding head and the associated bearing surfaces of the head support.

Sec. 28.14
METHOD NO. 5 Utilizing Remote Surfaces

PROCEDURE:

Sometimes it is possible to utilize distant surfaces as a Datum Plane when leveling the face of the column parallel to the original factory surface. For example, the flat ways of the head support shown in Fig. 28.3, when in good condition, may be used as a check point on which to place the instrument. By leveling the flat ways of the head support, the face of the column is itself automatically leveled to the original plane.

Another possible check point might be the gib bracket bearings of the head support represented in the same figure. These surfaces originally were scraped parallel to the column face and since they are not a sliding bearing they would not be worn. However, their usefulness as a check point would be destroyed if they have become warped. Furthermore, their value would be nil if, at the time of manufacture, or at a subsequent rescraping, shims in varying amounts were inserted under the gib brackets, in lieu of accurate scraping, to provide the necessary clearance for the Sliding Head.

When the column face is correctly positioned, by utilizing any of the methods above outlined, the scraping may proceed.

Sec. 28.15
OBJECTIVES: The Face of the Column

1. To be parallel to the plane of the original factory-new surface.
2. To be flat.
3. To have a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

Essentially OBJECTIVE NO. 1 is the determination of the plane of the original factory surface. How to locate this plane has been discussed in detail in the sections immediately preceding. In suggesting these methods it has not been our purpose to inculcate a rigid formula. Consequently, the exercise of independent judgment will be required of every operator. After the plane is determined and the face of column positioned, every effort should be made to scrape straight down. Successfully practiced, this will effect the removal of the minimum amount of metal which, coupled with frequent testing, will facilitate the attainment of OBJECTIVE NO. 1.

Spotting is performed with a SURFACE PLATE and a STRAIGHT EDGE used alternately.

Repeating the Pivot Test and the X Test at frequent intervals will give warning of the onset of convexity in the incipient stage.

Since the face of column is the Datum Point of the machine, special care should be exercised to perform an accurate job on this surface. It should not be slighted in any particular because on its accuracy will depend, to a large extent, the reliability of many future alignment tests. Careful work at this stage is amply rewarded later.

All three OBJECTIVES must be achieved simultaneously.

Sec. 28.16

OBJECTIVES: The Guiding Way of the Column

1. To be parallel with the plane of the original factory surface.
2. To preserve the original angle of the angular way.
3. To be flat.
4. To have a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

Turn the column to the position shown in Fig. 28.6. Although this is a disadvantageous position which necessitates working the guiding way at an angle, precision spotting and scraping is nonetheless required because many alignment tests will be made from this surface.

Spotting of this surface is performed most easily with a standard STRAIGHT EDGE. However, if the structure of the column makes this impossible an ANGLE STRAIGHT EDGE will qualify. Precautions should be taken not to commit any of the errors described in Sec. 9.18.

The guiding way should be spotted and tested for flatness and alignment with the original plane before any scraping is attempted. From the results of these tests the scraper must determine what needs to be done, then utilize his skill in scraping to achieve a plane parallel to the original factory surface.

It is just as important to attain OBJECTIVE NO. 1 as it was to achieve the equivalent requirement when treating the face of column. The same reason, as given previously, applies in the present instance.

In addition to the difficulties of spotting and scraping this surface, due to its location, testing must also be conducted under a similar handicap. This is unavoidable because it would be an extremely formidable undertaking to position the casting so that this surface could be leveled. Consequently, a PRECISION LEVEL cannot be laid directly on it to facilitate checking the progress of the scraping.

Fortunately, however, there are several other methods which can be of considerable assistance. For example, by attaching a DIAL INDICATOR to an arbor, as shown in Fig. 28.6, the movement of the sliding head can be utilized to indicate the scraping trend. Gyrations of the DIAL pointer will be moderated after the guiding way has been scraped relatively flat.

As a variant of this method, a test bar may be inserted in the spindle and the guiding way tested to the bar using a DIAL INDICATOR with indicating jig, as represented in Fig. 28.7.

To test for OBJECTIVE NO. 2, a vernier protractor is often employed. The original angle can be determined, prior to

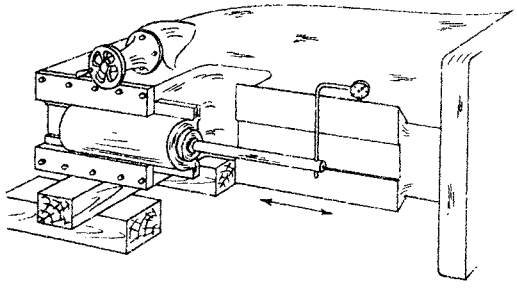

Fig. 28.6 View showing method of using movement of sliding head to check guiding way for parallelism with plane of original factory-new surface.

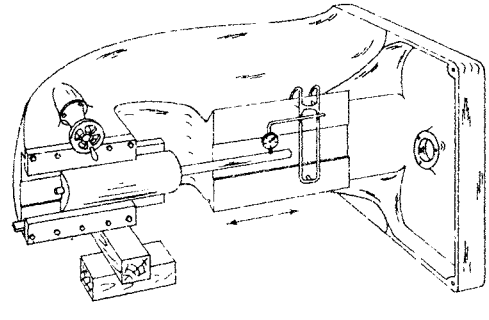

Fig. 28.7 Alternative method of testing a guiding way for parallelism with original factory-new surface.

scraping, by measuring between the column face and guiding way at the point where the surfaces are least worn. This angle has been standardized by the manufacturer and should be duplicated.

In lieu of the protractor, the scraper can make up a DOVETAIL TEMPLATE having the desired angle. If the latter course is adopted, this gage can also be employed to form an identical angle in the gib way, which is the next surface treated. The application of either tool will assist in satisfying the requirements of OBJECTIVE NO. 2.

A correct spotting and scraping technique will yield results that fulfill OBJECTIVE NO. 3 and OBJECTIVE NO. 4.

All OBJECTIVES must be achieved simultaneously.

Sec. 28.17
OBJECTIVES: The Gib Way of the Column

1. To duplicate the angle of the guiding way.
2. To be parallel to the guiding way.
3. To have a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

The column is turned 180° from the former position. The gib way is now uppermost.

To accomplish OBJECTIVE NO. 1 expeditiously, a DOVETAIL TEMPLATE is ideal. If one was constructed for the purpose of treating the previous surface, it can again be employed to good effect here. In case the operator is obliged to use a vernier protractor to maintain the angle, it would be well to sight under a good light to assure the maximum accuracy.

A STRAIGHT EDGE is applied for spotting purposes to help keep the surface flat and develop good bearing quality.

An indicating jig, similar to that described in Sec. 16.13 should now be constructed. This device, in conjunction with a DIAL INDICATOR, is suitable for checking parallelism. Tests should be made occasionally as the scraping promotes conditions favorable to the speedy accomplishment of OBJECTIVE NO. 2.

Complete all three OBJECTIVES together.

The three bearing surfaces on the column proper, viz: The face, the guiding way, and the gib way are now completed. While the column is still in a prone position it is advisable to scrape the bearing surfaces of the head support.

Sec. 28.18
The Head Support

The bearing surfaces, comprising the upper position of the main casting, guide the sliding head. Fig. 28.8 shows that, in the example being discussed, they are of square edge construction. They are enumerated in the proper sequence for scraping, as follows:

The flat ways of head support
The guiding way of head support
The gibbed surface of head support
The gib bracket bearings of head support

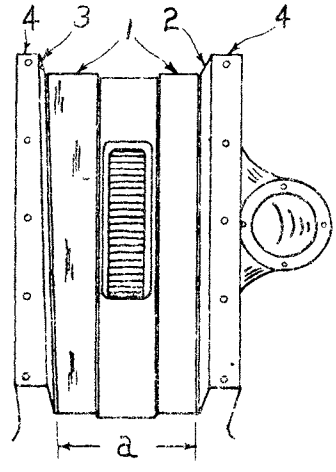

Fig. 28.8 View of head support showing surfaces.

(1) flat ways (2) guiding way (3) gibbed surface (4) gib bracket bearings (Maximum permissible width of special surface plate equal to "a".)

Sec. 28.19
OBJECTIVES: The Flat Ways of the Head Support

1. To be parallel to the column face.
2. To be flat and have a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

Fig. 28.8 shows the situation confronting

the scraper. From a study of the illustration it is obvious that a special type SURFACE PLATE of a definite width is required for spotting this job. The preparation of such a tool is begun by machining a 1" thick plate of cast iron, or semi-steel, to a width indicated by the dimension "a" in Fig. 28.8. This is the maximum width which will fit into the available space. As for the other dimension, the length should slightly exceed the length of the flat ways. One surface of this tool is scraped to SURFACE PLATE quality. When completed it is used to spot the head support flat ways.

The construction of this gage does not end our difficulties. We will find, as we prepare to use it, that the taper between the guiding way and the gibbed surface constitutes another problem. The taper condition prevents the entire area of the flat ways from being spotted at one time unless the tool is manipulated sidewise as well as lengthwise. This technique is unwise because it may produce false markings which, if accepted at face value and scraped, could generate a convex surface.

It is preferable to employ a straight line push and pull movement. This spotting procedure requires holding one edge of the special type SURFACE PLATE against the guiding way, then in the following cycle, against the gibbed surface, and so on, alternately. Such a technique will prevent the formation of a ridge on the flat ways near either of the adjacent surfaces and will discourage the formation of a convex surface. Proper use of the tool will also help materially in satisfying OBJECTIVE NO. 2.

To test for OBJECTIVE NO. 1, i.e., to determine the parallelism of the head support flat ways, measurements are made directly from the Datum Point, which is the column face. In other words, the column face is adopted as a check point for the flat ways of head support. Since these two surfaces are separated by quite some distance, any attempt to bridge between them by a direct connection, such as a long rod attached to a Surface Gage, and holding a DIAL INDICATOR, becomes somewhat unwieldly and impractical. However, thoroughly satisfactory results may be achieved by using the PRECISION LEVEL.

One suggested set-up is illustrated in Fig. 28.9. In this method the face of the column is adjusted to dead level as closely as possible, and the casting is blocked solidly. Then scraping is begun on the flat ways of the head support. To assure aligning these surfaces parallel to the face of the column, leveling tests are performed periodically. The PRECISION LEVEL is laid alternately cross-wise and lengthwise on the flat ways.

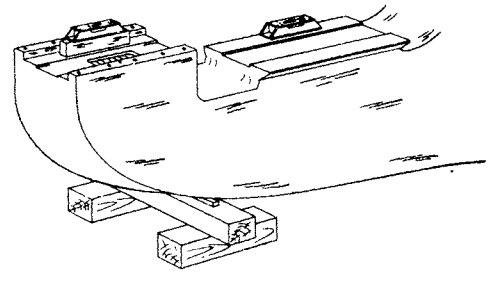

Fig. 28.9 Showing set up for testing parallelism of flat ways of head support to Datum Point using a PRECISION LEVEL. (longitudinal direction)

A maximum tolerance of .0005" in 8" is allowed in a longitudinal direction, which is the critical alignment. The flat ways may deviate from parallelism with the face of the column in the transverse direction by the usual scraping tolerance for non-critical surfaces.

Both OBJECTIVES are brought to completion simultaneously.

Incidentally, to answer a question which may have occurred to the reader, we do not use a STRAIGHT-EDGE on these flat ways because it is necessary to keep both ways in the same plane. There is no assurance that this could be done if each surface was spotted independently of the other.

NOTE: In actual practice the flat ways of the head support are done immediately after the column face is scraped, and before turning the casting. This eliminates the necessity of re-leveling the casting and speeds up the work. The present arrangement is followed in order to promote operational comprehension and to make easier the understanding of the principles involved.

Sec. 28.20
Alternative Method of Treating the Flat Ways of Head Support

This is a convenient point at which to pause and suggest an alternative method of dealing with the flat ways that, in certain circumstances, is preferable to the one just described. As the reader will recall, we have recommended the preparation of a special template to spot the flat ways of the head support. To be at all trustworthy, this gage must be precision scraped, which involves an operation requiring considerable time and tedious effort.

Under some conditions it might be possible to forego constructing the special template altogether and instead change the sequence of scraping operations so that the sliding head is scraped first. This member does not require a special template and can be spotted with standard spotting tools. When completed, the sliding head can then be adapted as a template to spot the head support bearing surfaces, including the flat ways. Should this procedure be followed the bearing surfaces of the head support must be fitted to the sliding head. Except for this there is no variation in the OBJECTIVES sought.

Sec. 28.21
OBJECTIVES: The Guiding Way of the Head Support

1. To be parallel to the guiding way of column.
2. To be square with the flat ways of Head Support
3. To have a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

The same difficulty is met with here as was experienced on the flat ways of head support, viz: excessive distance from the column bearing surfaces serving as the Datum Point. Since the distance is too great to be bridged conveniently, an indirect set up to cope with the situation is discussed.

Fig. 28.10 shows a convenient method of preparing a check point. A PRECISION LEVEL is placed on a PRECISION ANGLE PLATE held against the column face as at "a". The column is adjusted until the position of the bubble in the glass vial indicates levelness.

A LEVELING STRAIGHT EDGE is placed next to the column and adjusted with the leveling screws until parallel longitudinally with the column guiding way. (In lieu of a LEVELING STRAIGHT EDGE, a conventional STRAIGHT EDGE placed upside down and provided with a means of adjustment may be used.)

Parallelism of the LEVELING STRAIGHT EDGE is judged by the reading of a DIAL INDICATOR fastened to an indicating jig at "b". The jig is moved back and forth meanwhile adjusting the screws under the LEVELING STRAIGHT EDGE until a zero-zero reading is secured. However, the top of the LEVELING STRAIGHT EDGE must be square with the column face, otherwise this reading will not be true. To assure this condition, a PRECISION LEVEL is placed on the LEVELING STRAIGHT EDGE, as at "c". The STRAIGHT EDGE is shimmed until

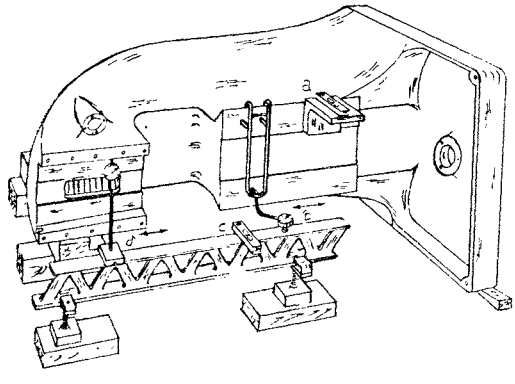

Fig. 28.10 Testing parallelism of guiding way of head support to guiding way of column.

the position of the bubble in the LEVEL is centered. When this is accomplished, a check point that is parallel longitudinally with the guiding way of the column and square with the column face has been established.

The test for OBJECTIVE NO. 1 is performed by setting a Surfage Gage with attached DIAL on the LEVELING STRAIGHT EDGE then placing the button of the instrument on the guiding way. By moving the Surface Gage along the STRAIGHT EDGE as at "d", while the button of the DIAL traverses the guiding way, the deviation from parallelism is registered.

Another suitable procedure is shown in Fig. 28.11. Here two SURFACE PLATES are adapted as Datum Planes. One is positioned near the column surfaces. The other is set close to the head support surfaces. Both are leveled by means of adjusting screws and checked for accuracy with a PRECISION LEVEL.

PLATE NO. 2. The button of the DIAL is placed on the guiding way of head support. It will make for greater accuracy if a pencilled line is drawn from end to end of this surface bisecting it lengthwise, and used as a guide line when moving the apparatus. Readings of zero-zero observed at the extremities of the guiding way indicate parallelism. A tolerance equivalent to .0005" in 8" of travel is permitted on this surface.

As the scraping proceeds a RIGHT ANGLE TEMPLATE is utilized to hold the guiding way square with the flat ways of head support. A STRAIGHT EDGE will help to keep the surface flat. These tools employed alternately will satisfy the requirements of OBJECTIVES NO. 2 and NO. 3. It might be well to point out that in lieu of the RIGHT ANGLE TEMPLATE, a TOOL MAKER'S SQUARE could be used.

Another expedient which may have advantages under some conditions, is to re-

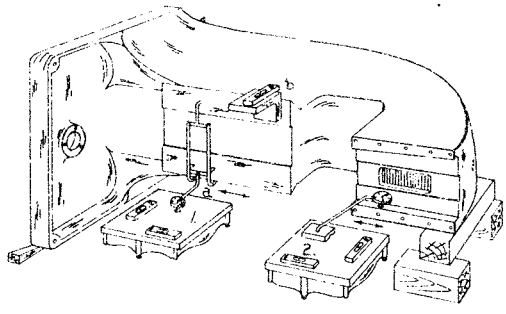

Fig. 28.11 Alternative set up for testing parallelism of guiding way of head support to guiding way of column.

Then the casting is shimmed so that the column guiding way is parallel with SURFACE PLATE NO. 1. This condition is indicated by the DIAL fastened to the jig at "a". Simultaneously, the face of the column is squared with the SURFACE PLATE. This is accomplished by placing a PRECISION LEVEL on a PRECISION ANGLE PLATE, as shown at "b" in the figure, and adjusting the casting until the bubble in the glass vial centers. Now that we have adjusted the guiding way of the column so that it is level, and also having squared the column face with the SURFACE PLATE, we can proceed to test for OBJECTIVE NO. 1 as follows:

A Surface Gage with attached DIAL INDICATOR is mounted on SURFACE

verse the order of scraping operations. That is to say, the sliding head could be scraped before the head support surfaces. When finished, it could then be adapted as a template to spot the guiding way of the head support. This course, however, is not always practical and each case needs to be judged individually.

All three OBJECTIVES must be concluded together.

NOTE: For clarity this surface is discussed in the sequence dealing with the head support. In actual practice, however, it is best to scrape it immediately after treating the guiding way of the column. This plan halves the number of times the casting must be turned, adjusted, and leveled.

Sec. 28.22

OBJECTIVES: The Gibbed Surface of the Head Support

1. To match (approximately) the original taper.
2. To be square with the flat ways of head support.
3. To have a surface quality of 4-5 bearing spots per square inch.

PROCEDURE:

The gibbed surface is not a sliding bearing surface and therefore probably needs no attention on account of wear. It should be checked, however, to determine whether the casting has warped and lost its flatness. If a warp has developed, spotting with a STRAIGHT EDGE will reveal its true condition.

Should rescraping be required, any chance taper that may be generated during the course of the work is acceptable because OBJECTIVE NO. 1 is not critical. However, holding the new taper fairly close to the original involves the removal of less metal and thereby saves time. It is recommended that this be done, particularly if there is any likelihood that the old tapered gib piece can be salvaged and used over again.

A RIGHT ANGLE TEMPLATE and a STRAIGHT EDGE applied alternately will keep the gibbed surface square with the flat ways as required by OBJECTIVE NO. 2. These gages will also assist in developing flatness and the correct degree of bearing quality.

Schedule the work so as to accomplish all OBJECTIVES simultaneously.

NOTE: A tapered gib piece will be required on this surface. Normally, though, it is not prepared until the sliding head is fitted to the head support surfaces. On a reconditioning job, the old gib piece may often be salvaged, rescraped, and re-fitted. If a new tapered gib is required as a replacement, the procedure of producing one can be studied in detail in Sec. 17.16.

Sec. 28.23

OBJECTIVES: The Gib Bracket Bearings of Head Support

1. To be parallel with the flat ways of head support.
2. To have a surface quality of 4-5 bearing spots per square inch.
3. Distance between the gib bracket bearings and the flat ways of head support to be equal to the distance between the front and back flat slides of the sliding head, plus an allowance for clearance.

PROCEDURE:

To treat the gib bracket bearings efficiently, the casting is turned so that they are uppermost, as represented in Fig. 28.9. In actual practice it is best to scrape them immediately following the completion of the flat ways of the head support. The time spent in turning and blocking the column would thereby be saved.

To test for OBJECTIVE NO. 1, a scraped PARALLEL is laid from one bracket bearing to the other, at one end of the head support. The distance from the top of the PARALLEL to the flat ways is gaged with a depth micrometer. This measurement is made near the guiding way and again close to the gib way. Then the PARALLEL is moved to the other end of the head support where the measurements are repeated. Identical readings at all four positions will satisfy the requirements of this OBJECTIVE.

Since the surfaces in question are not intended for sliding bearing, OBJECTIVE NO. 2 is easily attained. It is only necessary to combine correct usage of a SURFACE PLATE and a STRAIGHT EDGE for spotting with careful scraping, particularly around the rim of the bolt holes.

The measurement required for OBJECTIVE NO. 3 is secured from the sliding head (Fig. 28.13) which is a separate member. Due to the fact that this is an indispensable calculation, it will be necessary to suspend temporarily further work on the gib bracket bearings and undertake without delay the scraping of the sliding head. For purposes of continuity, however, we will assume that the latter member has been scrape-finished and the dimension is available. Briefly, the information is acquired by applying a micrometer from the front flat slides to the back flat slides of the sliding head. This dimension is matched with a similar gaging between the flat ways and gib bracket bearings of head support. The latter named surfaces must be scraped

until this distance is equalled.

An allowance for working clearance amounting to approximately 1/2 to 1 thousandths of an inch (.0005" to .001") is necessary. In other words, we must increase by this small amount the dimension obtained from the sliding head member. With the gib bracket bearing modified to this extent the sliding head member will move freely under the gib brackets. These attachments are discussed next.

Sec. 28.24
OBJECTIVES: The Gib Brackets of the Head Support

1. To be flat on one side and have a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

Production of the two gib brackets of the head support is an elementary operation because essentially they are simply flat castings. (See Fig. 28.12) To indicate the degree of flatness and surface quality, a SURFACE PLATE is appropriate for reverse spotting.

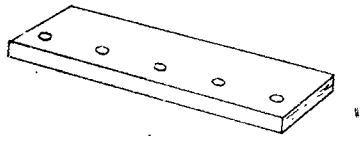

Fig. 28.12 Diagram of gib brackets of head support. (One surface is hand scraped.)

These components have a sliding bearing contact on only one face. Consequently, scraping is limited to but a single surface of each bracket. Simple as this operation will prove to be, it should not be slighted.

All surfaces and members associated with the ways of head support have been scrape-finished, and we can now proceed to a discussion of the next member, the Sliding Head.

Sec. 28.25
The Sliding Head

The sliding head consists of a casting enclosing the spindle and supporting a raising and lowering mechanism etc. This component is positioned within, and bears against the head support surfaces. Fig. 28.1 shows it in relation to other members of the machine. Front and back views of the sliding head are illustrated in Fig. 28.13.

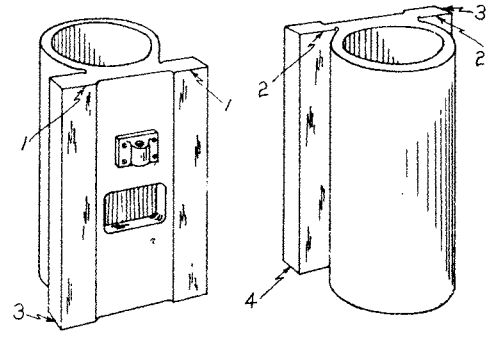

Fig. 28.13 View showing sliding head (front and back) (1) back flat slides (2) front flat slides (3) guided slide (4) gib slide.

This member has four bearing surfaces which are scraped, in the order enumerated below.

1. The back flat slide of sliding head (a divided surface).
2. The front flat slide of sliding head (a divided surface).
3. The guided slide of the sliding head.
4. The gib slide of the sliding head.

The sliding head is the second member of the Vertical Milling Machine to be treated. Under some conditions, it is feasible to scrape-finish it before working on the head support bearing surfaces, though ordinarily it is scraped afterwards as described here.

Sec. 28.26
Proving Accuracy of Spindle as a Check Point

Before work is started on the sliding head, make sure that the spindle is accurate and dependable because its axis will be utilized as a check point for various surfaces. To certify the truth of this part, three separate tests are performed. For convenience' sake the sliding head member is placed on a work bench and

the spindle is tested with a DIAL INDICATOR and Surface Gage, as follows:

Test No. 1 Spindle End Periphery Run Out

Fig. 28.14 shows the periphery of the spindle end being tested for run out. The position for the button of the DIAL INDICATOR is in contact with the rim at the spindle end, or just inside the tapered hole, or both places in succession if maximum testing precision is desired. Then the spindle is revolved by hand. A tolerance of .0002" is allowed.

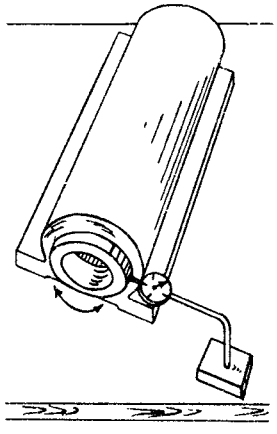

Fig. 28.14 Testing spindle end periphery run out. Tolerance max. .0002".

Test No. 2 Spindle End Face Run Out

In Fig. 28.15 we show the face of the spindle being tested for run out. The contact button of the DIAL INDICATOR is positioned on the face of the spindle which then is revolved by hand. The permissible tolerance of .0002" must not be exceeded. It was shown in Sec. 16.11 on Cam Action, why this test is so important.

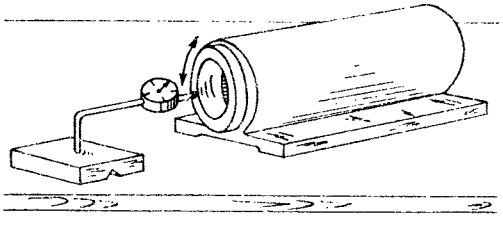

Fig. 28.15 Test for spindle end face run out. Tolerance max. .0002".

Test No. 3 Spindle Run Out

The procedure followed in this test is to insert a test bar into the tapered hole in the spindle. It is essential that the test bar be properly seated. (In this connection the reader might find it helpful to reread Sec. 15.6.) The button of a DIAL INDICATOR is now positioned on the test bar as shown in Fig. 28.16. While revolving the spindle, the test bar is checked, first at the spindle end, then at the free end. A tolerance of .0005" at 1-1/4" from the spindle, and .001" at 12" is permitted.

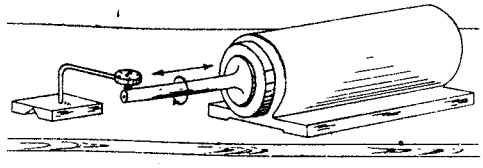

Fig. 28.16 View showing test for spindle run out. Tolerance max. .0005" at 1 1/4" from end of spindle. Tolerance max. .001" at 12" from end of spindle.

If the tolerance is exceeded on any of the three aforementioned tests, the spindle must be corrected. This may involve regrinding the tapered hole in spindle, the replacement of worn spindle bearings etc. These matters, however, are outside the scope of this book. Whatever the defect, it must be rectified before proceeding to the scraping operation. The reason for this insistence, as we have mentioned above, is that the correct alignment of the slides of the Sliding Head is determined from the axis of the spindle which thus becomes the Check Point.

Sec. 28.27

OBJECTIVES: The Back Flat Slides of the Sliding Head

1. To be parallel to each other.
2. To be fitted to the flat ways of head support with a surface quality of 10-15 bearing spots per square inch.
3. To be parallel to the spindle axis.

PROCEDURE:

It is an axiom in the scraping art that

the operator should always begin on that surface that will most swiftly advance the work to a conclusion. This is the basis for choosing the back flat slides of the sliding head as the initial surface to be scraped. Reference to Fig. 28.13 shows it to be a divided surface, but unlike the front flat slides of the same member, it is not separated by an elevated obstruction and consequently is easier to work.

These surfaces are most easily spotted on a SURFACE PLATE, although some operators prefer to spot them on the flat ways of head support. This is entirely feasible since the flat ways of the head support have already been completed. Therefore, marking compound is spread on them and the back slides of the sliding head are tested for a fit. (Refer to Sec. 22.14 and Sec. 22.15 on Fitting) With judicious scraping an area contact is quickly realized satisfying OBJECTIVE NO. 1 and OBJECTIVE NO. 2. The back flat slides of the sliding head must be scraped until this characteristic is obtained.

At the same time it is essential to align this surface parallel to the axis of spindle. Since we know from the preceding series of tests in Sec. 28.26 that the spindle and the spindle bearings are true, we can proceed with confidence to proove the slides for parallelism as follows:

The sliding head is laid on a SURFACE PLATE and a test bar is inserted in the spindle, as shown in Fig. 28.17. The test bar should be ground to fit the tapered spindle hole but a portion, at least 12" long, is ground cylindrical for use as a target. Before testing for parallelism, the bar must be checked for run out. To do this a Surface Gage with attached DIAL is placed on the SURFACE PLATE. The button of the device is set in contact with the test bar at the free end "a" as represented in Fig. 28.17. The spindle is rotated by hand and the reading on the DIAL observed. A maximum tolerance of .001" at 12" from the spindle is allowable. If this is exceeded, either the spindle is at fault, or the test bar is not correctly seated in the tapered hole of the spindle.

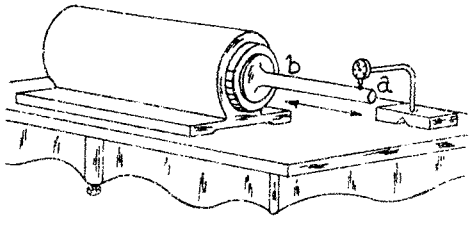

Fig. 28.17 Testing alignment of back flat slides of sliding head to spindle axis.

"a" position tested at free end of test bar.
"b" position tested near spindle end of bar.

Of these alternatives, it is less probable that the spindle will now be deficient, if the tests mentioned previously were conscientiously performed and corrective action taken where necessary. (Tests for accuracy of test bars have been given in detail in Chapter 15. The reader is advised to refer thereto and refresh his memory.) More likely, the trouble may be a speck of grit which prohibits proper seating of the test bar. The seating of the bar must be trued before proceeding.

At the risk of being tedious, here are a few words to explain the inclusion of such a lengthy and repetitious subject. First, the test bar must be removed while scraping and spotting the back flat slides. Second, every time it is desired to check the progress of the work, the test bar must be re-inserted. Third, if the alignment test is to be accurate and dependable the bar must be seated properly. Fourth, this condition cannot be verified unless a run-out test is performed each and every time. If the test bar meets specifications, it is turned so that the mean position of eccentricity error is at the vertical diameter. Now the back flat slides are checked as follows:

Still referring to Fig. 28.17, the DIAL button is moved across the test bar at the vertical diameter. Checks are executed first at position "a" then at position "b". The maximum effectiveness can be expected from such a test only if it is conducted from the mean position, thereby minimizing eccentricity. A tolerance of .0005" in 12" travel is permissible. The back flat slides are scraped until the necessary accuracy is achieved.

All OBJECTIVES are completed simultaneously.

Sec. 28.28

OBJECTIVES: The Front Flat Slides of Sliding Head

1. To be parallel to the back flat slides.

2. To have a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

The front flat slides of sliding head illustrated in Fig. 28.13 present a different problem than the back flat slides which were scraped previously. Treatment of these surfaces is complicated somewhat by an obstruction which divides them. This necessitates checking them for parallelism in the transverse direction, by the method described in Sec. 25.6.

A micrometer, measuring between the front and back flat slides at all four corners, will easily determine parallelism in the vertical direction. The maximum tolerance allowed for deviation from parallelism on these surfaces is .0005" in 24".

A STRAIGHT EDGE is the appropriate tool for the operator to employ in spotting and indicating the required surface bearing quality.

The scraping process should be synchronized so that both OBJECTIVES are satisfied at one time.

NOTE: When the front flat slides are completed, measurements are made of the distance between the back and front slides. We must have this dimension in order to scrape to precise limits the gib bracket bearings of the head support discussed in Sec. 28.23.

Sec. 28.29

OBJECTIVES: The Guided Slide of the Sliding Head

1. To be fitted to the guiding way of the head support with a surface quality of 10-15 bearing spots per square inch.
2. To be parallel to the spindle axis.

PROCEDURE:

In treating this surface it would be highly desirable to keep it square with both the back and front flat slides, shown as (1) and (2) respectively in Fig. 28.13. However, our primary concern is to fit the guided slide to its mateing surface; and therefore we must forego this purely theoretical requirement for practical reasons. Since the scrape finished mateing surface, i.e., the guiding way of head support may tolerate a slight error, this imperfection will be duplicated on the guided slide in the course of matching the surfaces. As a result the guided slide may not be perfectly square with adjacent surfaces. This is unavoidable, but it will not impair in any way the operation of the machine.

In addition to using the mateing member as a spotting template, it will facilitate the work to spot alternately with a STRAIGHT EDGE.

As the scraping work proceeds, test periodically for the parallelism sought for OBJECTIVE NO. 2. Place the sliding head on a SURFACE PLATE with the guided slide in contact, as in Fig. 28.18.

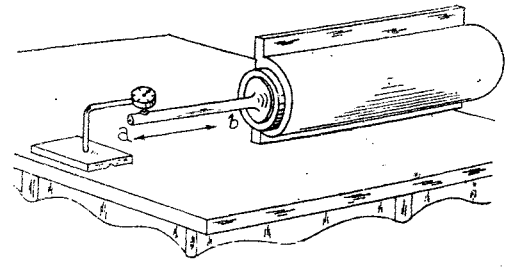

Fig. 28.18 Correct method of resting guided slide on SURFACE PLATE when testing for parallelism with axis of spindle.

"a" position tested at free end of test bar.
"b" position tested near spindle nose.

It is essential that the guided slide rest firmly on the SURFACE PLATE. If canted so as to touch on an edge, a line contact would result. This might occur if it were clamped to an ANGLE PLATE, as shown in Fig. 28.19. Such a test would be meaningless since it would be sheer coincidence if the edge was parallel to the guided slide. As a matter of fact the

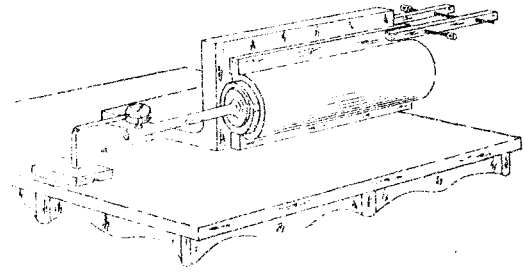

Fig. 28.19 Incorrect method of testing alignment of guided slide to axis of spindle.

sharp edge is often filed to a slight bevel to minimize the danger of cutting the hand. In short, the test should never be made with the sliding head clamped. To insure an area contact of the guided slide with the SURFACE PLATE, experienced operators make it a practice to steady the member by hand.

The test for OBJECTIVE NO. 2 requires a test bar to be inserted in the spindle. Make certain that the test bar is correctly aligned to the axis of the spindle by adopting the same checking procedure that was used previously with the back flat slide. In brief, test for run out and turn the test bar until the mean position of eccentricity error is at the vertical diameter. Then move the DIAL button across the top of the bar, first at the free end, "a", then at "b". By doing this we check the parallelism of the guided slide with respect to the axis of the spindle. The deviation from parallelism with the spindle should not exceed .001" in 12". The scraping operation is continued until the parallelism demanded by OBJECTIVE NO. 2 is achieved. Both OBJECTIVES must be completed together.

Sec. 28.30
OBJECTIVES: The Gib Slide of the Sliding Head

1. To be parallel with the guided slide.
2. To be square with the flat slides.
3. To have a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

It will be noted from Fig. 28.1 that the gib slide is designed for sliding bearing contact with a tapered gib. Consequently, it must be carefully scraped and be given a good bearing. While the scraping routine is being conducted tests should be made from time to time to determine proximity to OBJECTIVE NO. 1. Parallelism in the longitudinal direction is checked by measuring with a large micrometer from the gib slide to the guided slide at both ends of the member.

Another method of testing parallelism is to stand the sliding head on a SURFACE PLATE with the guided slide in contact with it. Then a Surface Gage and attached DIAL INDICATOR are placed on the Datum Plane whereupon measurements are made to the gib slide. Readings are taken at both ends. Scraping is continued until the desired parallelism is secured. A scraping tolerance of .001" in 12" is allowed.

A RIGHT ANGLE TEMPLATE will assist in attaining OBJECTIVE NO. 2. By keeping the gib slide square with the flat slides of the sliding head there is assurance that the taper gib when fitted will not have an undesirable transverse taper. The gib slide will thus be parallel with the gibbed surface of the head support.

All OBJECTIVES are completed simultaneously.

Sec. 28.31
Tapered Gib

All bearing surfaces of the sliding head having been completed, a tapered gib piece is now fitted. To accomplish this both the gib slide of the sliding head and the gibbed surface of the head support are coated with a thin film of marking medium. The sliding head is set in place, and the gib brackets are bolted on. If the old gib piece is useable it should be inserted and tested for fit as required by the following OBJECTIVES. When conditions warrant making a new tapered gib, measurements are made and the part is produced in the usual manner discussed in the paragraphs beginning with Sec. 17.17. The reader is therefore advised to review this outline before proceeding with the study of the present chapter.

Sec. 28.32
OBJECTIVES: The Tapered Gib of the Sliding Head

1. The straight side to be fitted to the gib slide of the sliding head with a surface quality of 10-15 bearing spots per square inch.
2. The tapered side to be fitted to the gibbed surface of the head support with a surface quality of 4-5 bearing spots per square inch.

PROCEDURE:

The fitting of the tapered gib is thoroughly explained in Sec. 17.24 and will not be amplified here, except to say that both OBJECTIVES are completed simultaneously.

Sec. 28.33
Testing the Alignment of Sliding Head to the Column

When the tapered gib piece is considered to be well fitted but before being completely finished, it is well to pause and evaluate the accuracy of the work thus far performed on the head support, the sliding head, and the gib piece. Checks should be instituted to determine, in so far as possible, if all the OBJECTIVES pertaining to parallelism, fit, and clearance have been attained. To this purpose we proceed as follows:

The ways of the head support and the slides of the sliding head are cleaned thoroughly and oiled. The sliding head is replaced on the column. Next the gib brackets are lightly bolted on, and the gib piece is inserted and adjusted for sliding pressure.

The sliding head should now be pushed back and forth and tested for "rock" to verify that the gib is properly fitted. If the head glides smoothly without any sticking as the gib piece is tightened by stages, it may be assumed that the gib slide and the guided slide of the sliding head are parallel.

The gib brackets should now be tightened progressively as the head is slid back and forth. If the head does not "rock" or stick appreciably when the brackets are fully tightened, we may assume that the back and front slides are likewise parallel and that the gib bracket bearings have been scraped properly, with allowance made for a separating lubricating film.

When these preliminary arrangements have been completed some scrapers prefer to test the alignment of the head with the column in the prone position. If this is desired the alignments may be performed as shown in the following series of figures. The set ups shown are self explanatory. Tolerances are indicated in the several diagrams.

1. The test of the axis of the spindle for parallelism with the guiding way of the column is shown in Fig. 28.20.
2. Fig. 28.21 shows the axis of the spindle being tested for parallelism with the column face.
3. In Fig. 28.22 the sliding head movement is tested for parallelism with the column face.
4. Testing the sliding head movement for parallelism with the guiding way of the column is shown in Fig. 28.23.

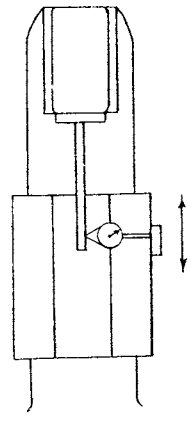

Fig. 28.20 Spindle parallel with guiding way of column. Tolerance max. .001" in 12".

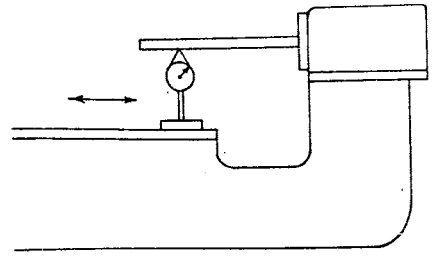

Fig. 28.21 Spindle parallel with column face. Tolerance max. .001" in 12".

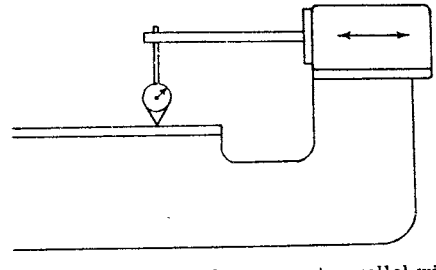

Fig. 28.22 Sliding head movement parallel with column face. Tolerance max. .0005" in 8".

Other operators prefer to postpone testing the alignment of the sliding head until the column is vertically erected with the head in the working position. These practitioners believe such a course is preferable because more rigid set ups can be used; that sag in test bars is

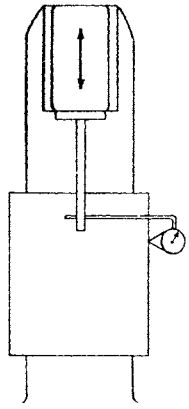

Fig. 28.23 Sliding head movement parallel with guiding way of column. Tolerance max. .0005" in 8"

reduced; and that conditions generally are more satisfactory for accurate testing. Since the author is partial to this argument, the latter procedure will be adopted and a thorough exposition of the alignment tests of the sliding head will be presented later.

Sec. 28.34
The Knee

As with similar types of milling machines, the knee of the Vertical Miller slides vertically up and down the column, guided by the column ways. The knee, in turn, guides the transverse movement of the saddle.

The knee member shown in Fig. 28.24 has six bearing surfaces identified by number. As a result of the assumed conditions discussed hereafter, the proper sequence of scraping these surfaces will be in the order they are enumerated, viz:

GROUP 1
1. Flat ways
2. Guiding way
3. Gib way

GROUP 2
4. Flat slides
5. Guided slide
6. Gibbed surface (for a flat gib)

NOTE: In case the slides show less deterioration than the ways, the order to be followed in scraping is reversed. That is to say, Group 2 precedes Group 1 as follows: Surfaces Nos. 4, 5, 6 and 1, 2, 3. Thus it should be clear that the sequence to be followed is not an arbitrary one but is based on substantial reasons.

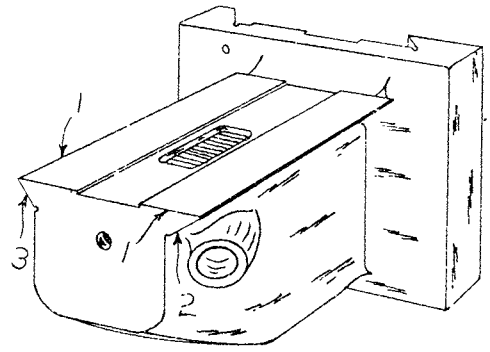

Fig. 28.24(a) Diagram of the knee of vertical milling Machine.
(1) flat ways (2) guiding way (3) gib way

Sec. 28.35
Organizing the Work

When scraping the several bearing surfaces of the knee member of a milling machine, both the vertical type that we are now discussing, and the horizontal type which is treated elsewhere, the operator is faced with the problem of what approach to use. In other words, he is confronted with the perplexing questions of "Where to start?" and "How?". Whatever decision is reached is based on the physical condition of the knee surfaces as determined

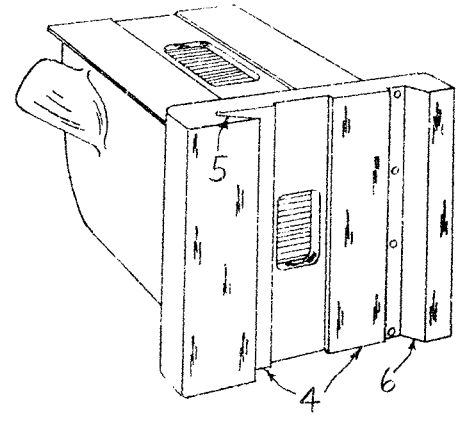

Fig. 28.24(b) Diagram of Knee of vertical milling machine.
(4) flat slides (5) guided slide (6) gibbed surface

by an Exploratory Examination.

In general there are two classifications of knee bearing surface conditions to be found on deteriorated milling machines, namely:

Case 1 Machines with both the ways and the slides about equally worn. For example, a tool room milling is devoted as a rule, to a wide variety of jobs and all members receive approximately the same degree of use.

Case 2 Machines with the ways obviously superior in condition to the slides, or vice versa. Typical of this is a milling machine devoted exclusively to repetitious manufacturing operations, wherein one member receives more frequent use than other members.

Broadly speaking, when the ways of the knee are so badly worn that there is little or no trace of the original factory surface, and this condition is equally true of the slides of the knee (Case 1 above), then it is advisable to produce the new surfaces parallel to the original plane using the following procedure:

The most thorough inspection should be given to all the bearings to gear every possible clue to the original factory-new surface. Then during the initial scraping cycles the slides and the ways of the knee are for a time worked jointly. This enables the scraper to utilize to the utmost, every scrap of available information.

When the direction of the goal is ascertained, the scraping is concentrated on the knee flat way and its adjacent guiding way and gib way. They are scrape-finished in succession, employing all of the information that has gathered. When completed, they should be as close to being parallel to the original factory surface as it is possible to make them. Incidentally, in this procedure only part of the estimated misalignment of the knee is corrected, the portion it is believed the ways are responsible for. The final alignment of the member is concluded when the slides are finish scraped and aligned.

An example of this procedure is outlined in the chapter on the horizontal milling machine. There, a detailed exposition is given of the steps to be taken in scraping a knee when it is practicable to prorate the misalignment between the ways and the slides.

On the other hand, when either the ways or the slides of the knee show unmistakable traces of some remnant of the original surface, or when the condition of one or the other group of bearings is unquestionably superior (Case 2 above), work should be started on it, and carried directly through to completion. This practice is advisable because the reconditioning of such a surface is comparatively easy. In this method no attempt is made to remove any part of the misalignment present in the knee member. Instead the scraping effort is concentrated on producing a bearing parallel to the original factory-new surface. Thus after one group of bearing surfaces, say the ways, is scrape-finished, the entire alignment of the knee member to the column is accomplished by scraping the other group of bearing surfaces, namely, the slides.

In actual practice, the operator will always conduct an exploratory examination of the knee before undertaking to remove any metal. Burrs are removed; the knee ways are spotted with a STRAIGHT EDGE or SURFACE PLATE; and the knee slides are spotted by being rubbed on the mating surfaces of the column. The markings thus transferred are then examined and the condition of the various bearings analyzed. From this information a working method can now be formulated.

To illustrate one of the problems of scraping the knee member of the vertical milling machine, shown in Fig. 28.24a and Fig. 28.24b, certain arbitrary conditions will be assigned to the knee surfaces. It will be noted that these hypothetical surface conditions are different from those discussed under the comparable member of the horizontal milling machine. (Chapter 27)

The reasons we advance for this change are: to demonstrate the use of other types of gaging tools; to bring out special points of interest, not heretofore discussed; to show how the OBJECTIVES for the same bearing surface, even on similar members, change under varying conditions; and lastly, to illustrate the best approach to scraping the knee under the existing assumed circumstances.

For the purpose of our discussion we will say that the bearing quality of the flat ways of the knee is definitely superior to that of the flat slides of the knee. Let us further suppose that the appearance of the flat ways is as illustrated in Fig. 28.25. This figure indicates that portions of the knee flat way, the extremities, are relatively unworn. In view of these factors, good practice prescribes that the ways of the knee will be scrape-finished first, followed by the slides of the knee.

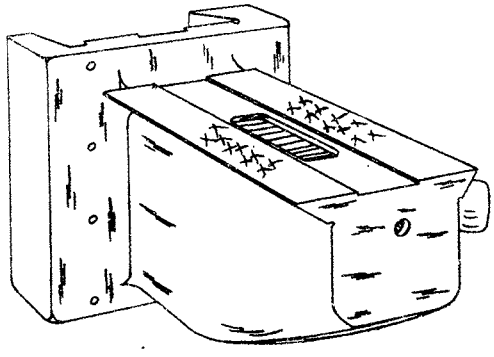

Fig. 28.25 View showing worn areas on flat ways of the knee.

In conclusion, it may be well for the operator to realize that, in actual practice, the condition of the bearing surfaces of most machines will vary in between the two extremes set forth in Case 1 and Case 2. It will be necessary, in such circumstances, for the operator to exercise his judgment and either proceed with the rather involved and laborious procedure as outlined in the chapter on the Horizontal Mill beginning with Sec. 27.15, or if conditions warrant, to adopt the simplified method discussed in the following pages.

Sec. 28.36
OBJECTIVES: The Flat Ways of the Knee

1. To be parallel to the original factory surface.
2. To have a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

After examining all the bearing surfaces of the knee, it was assumed, in our imaginary case, that the ways are less worn than the slides. Therefore, the knee flat ways will be the first surface to be scraped. We further assume that the scraper tool marks are distinguishable at the front and rear of this surface and that there is some evidence of deterioration in the middle portion, as depicted in Fig. 28.25. This condition, though hypothetical here, is in fact frequently met with on machines devoted to manufacturing purposes. It is quite probable that in the case illustrated, the saddle was locked most of the time at the middle of the knee and moved seldom. This favored the ways. The knee on the other hand, was raised and lowered repeatedly to provide variations in the required milling cut. This intensified wear on the slides. Since a pattern of wear, such as shown by the flat ways, is more easily restored to a plane parallel to the original factory surface, it would therefore be dealt with first.

From the condition of the surface it is apparent that the existence of scraper tool marks, at both the front and back of the flat ways, provides the operator with an excellent opportunity of attaining OBJECTIVE NO. 1. Either of two procedures is appropriate, for example:

First, by alternately spotting the surface with a SURFACE PLATE and a STRAIGHT EDGE and by scraping "straight down", the goal can be attained easily without any material deviation. Second, if the operator wishes to be more certain of his course, he may establish a Check Point, as illustrated at "a" in Fig. 28.26. If this system is to be utilized, the knee is leveled, prior to any scraping, by placing a PRECISION LEVEL on the unworn areas. Then the Check Point is bolted on, leveled, and securely locked. With this device the operator may detect and rectify any deviation from OBJECTIVE NO. 1 by merely re-leveling the Check Point and then laying the PRECISION LEVEL back on the work surface to test it.

The alternate use of the spotting tools mentioned above, coupled with judicious scraping, advances both OBJECTIVES to completion simultaneously.

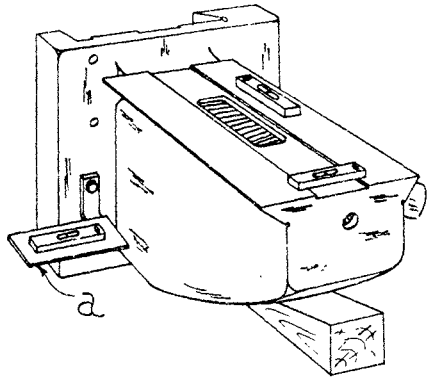

Fig. 28.26 Utilizing check point "a" to insure that flat ways will be kept parallel with original factory-new surface.

Sec. 28.37
OBJECTIVES: The Guiding Way of the Knee

1. To be parallel to the original factory surface.
2. To be a duplicate of the original angle of angular way.
3. To have a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

In our hypothetical case the guiding way shows a condition similar to that of the flat ways. To wit: The scraper tool marks are clearly distinguishable at the front and back, indicating little wear on these parts of the surface, while pronounced signs of deterioration are concentrated in the middle portion (See Fig. 28.27)

By scraping the guiding way "straight down" the operator will keep the new surface parallel to the original factory plane, thereby accomplishing the OBJECTIVE NO. 1. This method is quite accurate enough for all ordinary purposes and permits the work to be done very quickly. For greater precision, though, it is advisable to establish a Check Point. This topic has already been adequately treated in a number of places, most recently in the preceding article, and it would be superfluous to repeat it so soon again.

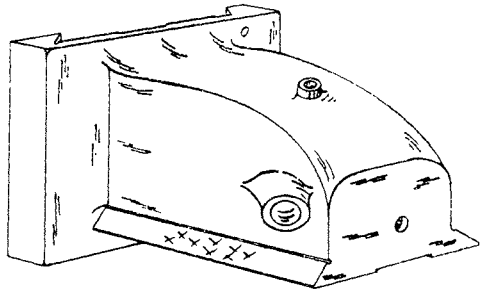

Fig. 28.27 View showing worn condition of guiding way of knee.

OBJECTIVE NO. 2 can be secured in either of two ways. One system calls for measuring the angle of the angular guiding way with a Universal Bevel Protractor before commencing to scrape. Then as the new surface is developed it is used to make repeated checks so as to duplicate the original angle.

Another satisfactory method calls for constructing a small DOVETAIL TEMPLATE. The pattern should be made by spotting it against the best preserved part of the angular guiding way, before that surface is altered by any scraping. With careful fitting, it can be fashioned so as to reproduce the original angle. After preparation, it is applied in the usual way.

A STRAIGHT EDGE alternated with either of the tools just mentioned, is most suitable for spotting the surface and for indicating flatness and bearing quality.

All three OBJECTIVES are achieved jointly.

Sec. 28.38
OBJECTIVES: The Gib Way of the Knee

1. Original angle of the angular way to be duplicated.
2. To be parallel with the guiding way.
3. To have a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

The condition of this surface, in our imaginary case, will most likely be similar to that of the guiding way. That is to say, a good bearing is probably evident at the extremities, while in the middle, definite signs of wear are apparent.

To achieve OBJECTIVE NO. 1, the same DOVETAIL TEMPLATE employed previously on the guiding way can be used again to duplicate the angle of the angular way. Otherwise the Bevel Protractor must be utilized.

The parallelism demanded by OBJECTIVE NO. 2 is best checked with an indicating jig, such as the one suggested previously for testing the column gib way. This jig will prove the parallelism of the gib way against two finished surfaces, namely: the guiding way and the flat way of the knee.

To keep the surface flat and indicate the bearing quality, the spotting is executed with a STRAIGHT EDGE. ALL OBJECTIVES are attained at the same time.

The ways of the knee having been completed, certain alignment tests are now performed on this member. Their purpose is to discover exactly how much to scrape from the slides of the knee to achieve the proper alignment of the ways of the knee to the column face, i.e., Datum Point. A fair accuracy is possible in spite of the uncompleted status of the member, because the ways, being finished, afford a smooth surface acceptable for test purposes. Three tests are conducted consecutively. No attempt is made to rectify the errors disclosed until all three checks have been concluded. The column remains horizontal throughout this operation.

Sec. 28.39
ALIGNMENT TEST NO. 1

Knee flat ways to be square with the column face, modified by the unilateral tolerance indicated in Fig. 28.28b.

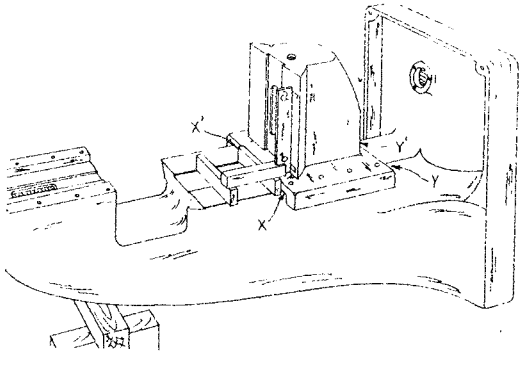

Fig. 28.28(a) Arrangement for checking alignment of flat way of knee to column face.

(a) and (b) positions for feeler stock (x) upper portion of knee flat slide (y) lower portion of knee flat slide.

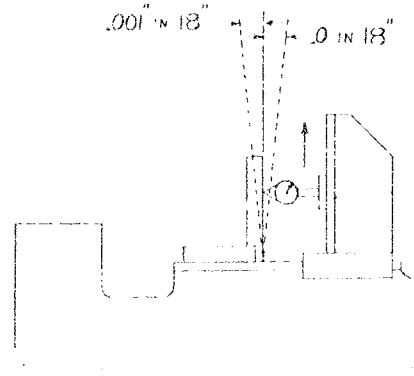

Fig. 28.28(b) Alignment of flat way of knee to face of column. (Side view) Unilateral tolerance max. .001" in 18" - high in front.

PROCEDURE:

The physical preparation for the tests is begun by coating the column face and the column guiding way with marking medium. Then the knee member is placed upon the column with the guided slide in contact with the column guiding way. The knee is pushed back and forth sufficiently to transfer the compound, then removed. Next the most pronounced high spots on both the flat slide and guided slide of the knee are scraped. This procedure is repeated a few times to obtain fairly flat surfaces free of roughnesses.

Having taken care of these essential preliminaries we can arrange the set up for alignment TEST NO. 1. This operation will be performed with the aid of a TRY SQUARE. (Sec. 13.2) The SQUARE is placed in proper position on two PARALLELS of equal thickness, as shown in Fig. 28.28a. For assurance of accurate results, the technique of "bucking" the SQUARE discussed in Sec. 13.7 should be re-read.

To test whether the knee flat way is square with the column face, feeler gages are inserted at positions "a" and "b" as shown. This is a trial and error procedure. If equal thicknesses of feeler stock inserted at both "a" and "b" exhibit an equal drag when pulled, then the flat ways of knee are square with the column face and hence are correctly aligned. In such a case, the operator need only scrape the knee flat slides "straight down" to produce the requisite bearing quality and complete the surface.

A small unilateral tolerance, shown in Fig. 28.28b facilitates the work, as it allows the front of knee to be tilted towards top of column and still be correctly aligned. Consequently, the feeler stock positioned 18" apart may be up to .001" thicker at "b" than at "a". This means that the front of knee is leaning toward the top of column but not so much as to exceed the tolerance. As always, proof of the appropriate thickness is indicated by an equal drag on both feelers. Should the feeler stock at "b" be more than .001" thicker than at "a", the front of knee is leaning too far toward the top of column. The flat slides of knee must be scraped to reduce the misalignment.

On the other hand, since our tolerance is unilateral, it prohibits absolutely any inclination of the front of knee away from top of column. This condition can be detected if the feeler stock at "a" is greater, by any amount, than the caliper of the feeler stock utilized at "b". If such a tilt is discovered, it must be rectified by scraping the flat slides of knee. (Remember, the flat ways have been scrape-finished and should not again be touched.)

In either of the two cases mentioned, the mis-alignment is corrected by scraping away a wedge shaped strip of metal. Whether the thick portion of the segment will be along the edge denoted as (y-y') or as (x-x') in Fig. 28.28a, will depend entirely upon whether the front of knee inclines toward or away from the top of column, respectively. This wedge of metal, which is scraped off to correct the alignment, will be over and above whatever amount it is necessary to remove to obtain the desired quality of bearing surface.

The TRY SQUARE should be set up first at one side of the divided flat ways and then at the other side. Tests for alignment are made at both sides.

Sec. 28.40
ALIGNMENT TEST NO. 2

The Guiding way of the knee to be square with the column face, modified by the unilateral tolerance indicated in Fig. 28.29b.

PROCEDURE:

The working arrangement for ALIGNMENT TEST NO. 2 is shown in Fig. 28.29a. Essentially it consists of an indicating jig with an attached DIAL INDICATOR. The jig rides the guiding way of knee and maintains stability through contact with the flat way of the same member. Meanwhile the DIAL button is adjusted to touch the blade of the TRY SQUARE.

The alert reader will note that Fig. 28.29a specifies the direction the indicating jig is moved when conducting this alignment test. This direction is "up" as shown by the arrow. If a zero-zero reading is observed, the guiding way is square

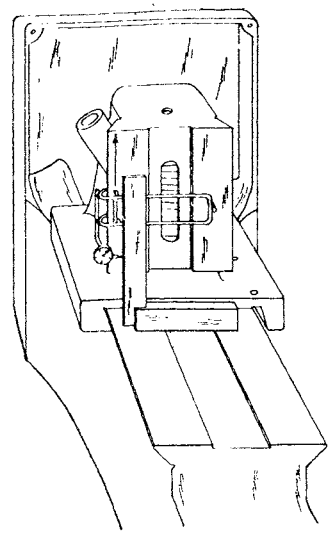

Fig. 28.29(a) Method of testing for alignment between guiding way of knee to face of column. (Column prone)

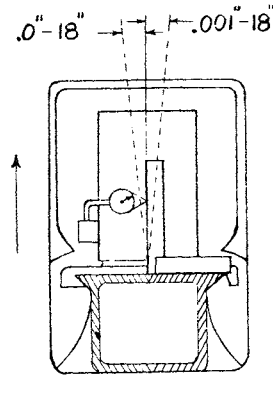

Fig. 28.29(b) Alignment of guiding way of knee to column face. Unilateral tolerance max. .001" in 18" in direction indicated. (End View).

with the column face. A perfect alignment is seldom obtained and in fact is not always desirable. (See Sec. 23.18 on Working Pressure) A small unilateral tolerance shown in Fig. 28.29b allows the knee guiding way to tilt slightly instead of being exactly square with the column face.

Since this is a unilateral tolerance, the tilt is permissible in only one direction. As the figure shows the DIAL INDICATOR moving in the direction indicated may register an error of as much as a plus (+) .001" in 18" of travel, provided the position of the DIAL and the SQUARE is as shown. If the tolerance is not exceeded, the operator need only scrape the flat slides "straight down" to obtain the required bearing surface. While so doing the current alignment must, of course, be maintained.

However, if in moving the apparatus "up", an error is observed surpassing a plus (+) .001" in 18", then the tilt of the knee though in the permissible direction will exceed the unilateral tolerance shown in Fig. 28.29b. On the other hand, should a minus reading be observed in moving the DIAL upwards, (the amount is immaterial) then the knee guiding way leans in the wrong direction. In either of the latter two cases, a wedge shaped section of metal must be scraped from the knee flat slides to align the guiding way. The amount of metal removed to obtain the essential alignment will be over and above that which is scraped off to produce the desired bearing quality.

The results of the tests so far conducted, i.e., ALIGNMENT TESTS NO. 1 and NO. 2 are combined, and the knee flat slide is scraped to the resultant of the errors disclosed by the two tests. However, as a time saving measure, it is advisable to conduct ALIGNMENT TEST NO. 3 before removing the knee from the column for scraping.

Sec. 28.41
ALIGNMENT TEST NO. 3

Knee flat ways to be square with the guiding way of column, modified by the unilateral tolerance indicated in Fig. 28.30b.

PROCEDURE:

Fig. 28.30a shows the set up for

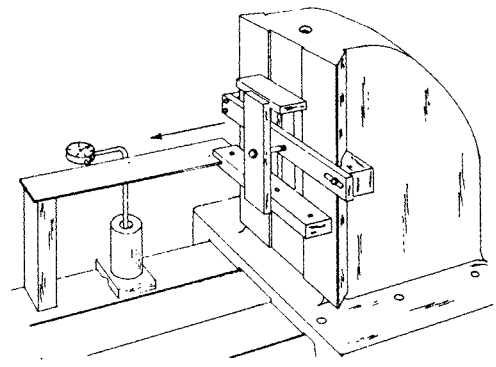

Fig. 28.30(a) General arrangement of apparatus for testing alignment of flat way of knee to the guiding way of column. To register a reading on DIAL the knee is pushed towards top of column as indicated by arrow. (Column prone).

ALIGNMENT TEST NO. 3. The beam of a TRY SQUARE is positioned against the knee flat way, then clamped by a suitable device. (See Fig. 28.31)

A Surface Gage with DIAL INDICATOR attached, is laid in any convenient place on the face of the column. The DIAL button should be in contact with the blade of the SQUARE. The Surface Gage remains stationary during the entire test. (To prevent movement it may be weighted if necessary.) While the guided slide of the knee is held in contact with the guiding way of the column, the knee is pushed towards the top of the column. If the DIAL registers a zero-zero reading, the flat ways of knee are square with the column guiding way.

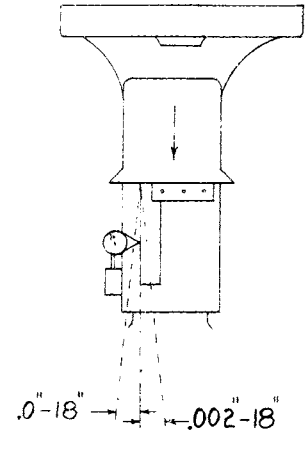

Fig. 28.30(b) Alignment of flat way of knee to guiding way of column. Unilateral tolerance. max. .002" in 18" in direction indicated. (Top view).

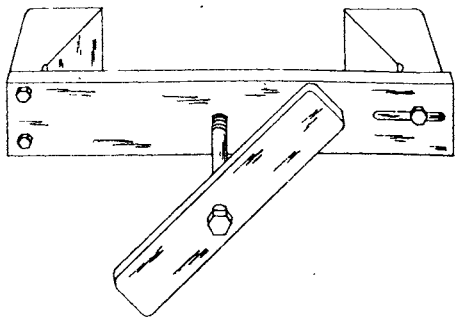

Fig. 28.31 Device for clamping TRY SQUARE to flat way of knee.

To expedite the job it is customary to allow a unilateral tolerance. Fig. 28.30b shows the maximum deviation permitted and also the direction it may take. This is relevant only if the set up is arranged as shown ir Fig. 28.30a and the knee is moved as indicated. In such a case, the DIAL may read a plus .002" in 18" of travel. If this is not exceeded, the tilt of the knee is within the limits of the unilateral tolerance, and the knee is correctly aligned in this direction. The guided slide then need only be scraped straight down as the required bearing quality is produced.

On the other hand, should the reading of the DIAL INDICATOR be greater than a plus .002" in 18", or show a minus reading of any amount, with the parts arranged as represented in the figure mentioned, the flat ways of knee are misaligned with respect to guiding way of column.

To correct the error in either of these cases, a wedge shaped piece of metal must be removed from the guided slide of the knee. The position of the thick part of the wedge will depend upon whether a plus or minus reading is observed. This segment of metal will be over and above whatever amount is removed to obtain a satisfactory bearing surface.

At the risk of being repetitious, we urge that all three alignment tests be completed, and the information correlated, before removing the knee and performing any scraping.

CAUTION: Check the groove for clearance.

Sec. 28.42

OBJECTIVES: The Flat Slides of the Knee

1. The requirements indicated by ALIGNMENT TESTS NO. 1 and NO. 2 to be satisfied.
2. To be fitted to the column face with a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

The face of the column member is coated with a marking medium, so it may be used as a spotting template. The knee is placed on the column to transfer the marking compound. On the basis of the markings observed, the knee flat slide is scraped. The amount of metal removed will depend upon the errors discovered in the tests just described. Essentially, two wedges of surplus material must be removed but since they overlap, the scraping is governed by the resultant of the two For additional description refer to Sec. 27.22.

As the scraping routine proceeds, ALIGNMENT TESTS NO. 1 and NO. 2 are, from time to time, repeated. Scraping is continued until OBJECTIVE NO. 1 is satisfied. The required bearing quality is produced simultaneously with the correct alignment.

NOTE: As a time saving measure, it is the practice of experienced operators to work the guided slide jointly with the flat slide. This reduces the frequency that the knee member must be placed on the column for spotting and testing purposes.

Sec. 28.43

OBJECTIVES: The Guided Slide of the Knee

1. To satisfy the requirement indicated by ALIGNMENT TEST NO. 3.
2. To be fitted to the guiding way of the column with a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

It is standard practice in working this surface, to test it at the same time that the knee flat slide is dealt with. This not only saves time but reduces effort, as the

knee can be placed on the column for spotting and testing both surfaces consecutively.

To spot the surface in question a film of marking compound should be applied to the guiding way of the column member and transferred to the guided slide of knee in the usual manner. An ANGLE STRAIGHT EDGE can be used for supplementary spotting.

It is advisable to interrupt the spotting and scraping routine occasionally, to repeat ALIGNMENT TEST NO. 3. This will enable the operator to keep tab on what remains to be done.

Both OBJECTIVES should be concluded simultaneously.

CAUTION: When spotting, engage and disengage the surfaces cleanly.

Sec. 28.44

OBJECTIVES: The Gibbed Surface of the Knee

1. To be parallel to the guided slide of knee. (An angular flat gib is to be used.)
2. To preserve the original angle (measured from the flat slide of knee.)
3. To have a surface quality of 4-5 bearing spots per square inch.

PROCEDURE:

As a rule, unless the knee casting has warped, the gibbed surface needs but little attention. To check for signs of warping, a STRAIGHT EDGE is used, but before doing this it is essential to get rid of all burrs, paint, and foreign material to render the surface safe for spotting.

If a warp is indicated, the gibbed surface requires scraping. In performing this operation, the scraper should strive to remove the minimum quantity of metal, while at the same time preserving the original angle. By so doing, it may be possible to salvage the old gib piece and thereby save the considerable work of constructing a new one. However, if too much metal is taken from the gibbed surface and from other surfaces influencing the position of the gib, the tapped holes for the adjusting screws in the old gib will not line up with the bolt holes in the knee adjacent to the gibbed surface. This in itself might necessitate discarding the old gib regardless of its suitableness otherwise.

When warping is not a factor, any scraping that is necessary will most likely be confined to satisfying OBJECTIVE NO. 1. The importance of this requirement has been taken up in detail in Sec. 17.12. To check for parallelism the indicating jig shown in Fig. 28.32 will be utilized.

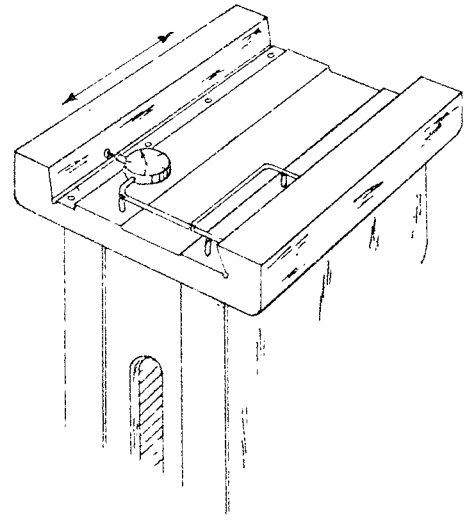

Fig. 28.32 Apparatus for checking the parallelism of gibbed surface to guided slide of knee.

The preservation of the angle required by OBJECTIVE NO. 2 is best accomplished by an appropriate OBTUSE ANGLE TEMPLATE. (See Fig. 28.33) However, if a new gib piece is to be produced this OBJECTIVE may be disregarded.

The gibbed surface of the knee is not a sliding bearing surface and therefore needs only a nominal number of bearing spots per square inch. OBJECTIVE NO. 3 is thus easily accomplished.

Sec. 28.45

OBJECTIVES: The Gib Piece of the Knee (An angular flat gib is utilized.)

1. One side to be fitted to the knee gibbed surface and provided with a surface quality of 4-5 bearing spots per square inch.
2. The other side to be fitted to the column gib way and provided with a surface quality of 10-15 bearing spots per square inch.

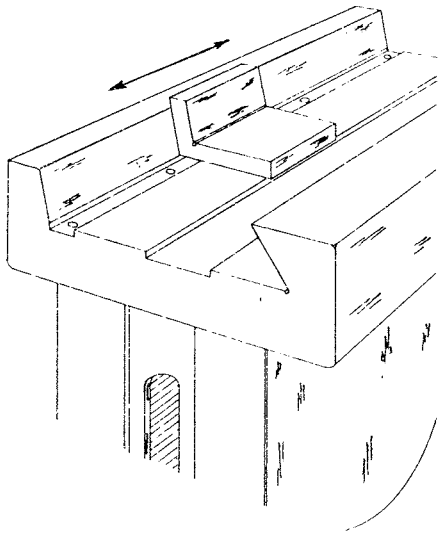

Fig. 28.33 Using OBTUSE ANGLE TEMPLATE to maintain the original angle on gibbed surface of knee.

PROCEDURE:

The angular flat gib required for the knee member is produced according to detailed instructions found in Sec. 17.11. All suggestions there recommended for the production and fitting of this type of gib should be complied with.

After both sides of the gib have been well fitted, but before the final bearing surface has been scraped in, the column ways should be tested for parallelism. This is the first opportunity to test the column ways by employing the actual mateing member. All previous efforts utilized an indicating jib and attached DIAL INDICATOR. Details of the Sliding Member Test are discussed in Sec. 22.11. Suffice to say that if a significant degree of either binding or looseness is noted in the knee, as it is moved along the column, there is a strong possibility that the gib way of the column is not parallel to the guiding way of column.

If this situation is noted the non-parallelism of the column ways must be rectified. This would entail rescraping the column gib way by whatever slight amount was required, and then re-fitting the gib piece. When the column ways prove to be parallel, the final surface bearing quality can be scraped into the gib piece.

It is also advisable at this time to test the slides of the knee for convexity. This can be done by applying the Shake Test. (Sec. 22.5) Should the test prove that the knee slides and gib piece are properly fitted to the column ways, it may be well to conduct ALIGNMENT TESTS NOS. 1, 2, and 3 (Secs. 28.39, 28.40 and 28.41 respectively) with the gib piece inserted and adjusted for sliding pressure. Eliminating any error discovered at this time will be easier while the column is in the horizontal position.

NOTE: Conditions are now favorable to touch up the ways of the column and the slides of the knee. Frequent sliding movements during tests of these two members will have caused a slight broadening in the area of some of the individual bearing spots with the result that they may appear to form a cluster. To assure maximum wearability on the bearing surfaces, these groupings should be divided, or split up, into separate bearing spots. (See Sec. 19.13 on Touching Up.)

Sec. 28.46
Frosting the Column

The next step is to frost the column if this refinement is desired. The sequence of frosting operations is similar to that used on the Horizontal Milling Machine. For particulars, the reader is referred to Sec. 27.33.

After the matter of decoration is attended to, the column is set up-right on its base and leveled. This procedure consists of placing the PRECISION LEVEL on the flat ways of the knee, then leveling the machine, transversely and longitudinally. The tolerance allowed is .0005" per 12". Having attended to this important detail, work on the Pedestal Boss may be started.

Sec. 28.47
OBJECTIVES: The Pedestal Boss

1. To be square with the face and the guiding way of the column.
2. To be flat and have a surface quality of 1-2 bearing spots per square inch.

PROCEDURE:

The pedestal boss is not, strictly speaking, a bearing surface. Nevertheless, its importance in the reconditioning

routine should not be minimized by the scraper. This component shown in Fig. 28.1 influences to a considerable extent the efficiency of the elevating mechanism of the knee.

OBJECTIVE NO. 1 must be satisfied before the pedestal is bolted to the boss and the elevating screw is attached to the knee. When the elevating screw is a nice threaded fit in the pedestal, the tolerance indicated in Fig. 28.34 and Fig. 28.35 is permissible. On the other hand, if the elevating screw is a sloppy fit in the pedestal, binding is less likely. A greater tolerance can be allowed if more play is apparent in this member.

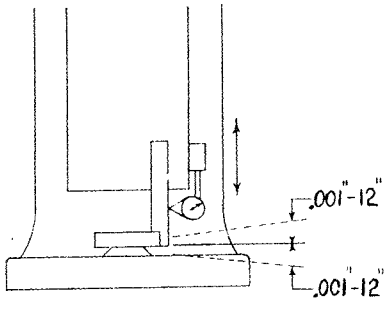

Fig. 28.34 Alignment tolerance for pedestal boss. Tolerance max. (±) .001" in 12" (Front view).

A surface that is reasonably flat is adequate for the pedestal boss, as indicated in OBJECTIVE NO. 2.

Sec. 28.48
Preparations for Testing the Sliding Head under Working Conditions.

The pedestal boss having been completed, the next operation is to bolt down the pedestal. Then the knee member is positioned on the elevating screw and all necessary gearing is replaced, including the elevating hand wheel. The knee gib is inserted and adjusted for correct sliding pressure. Next the sliding head is mounted and its gib piece is tightened for sliding pressure.

At this point, with the column in an upright position, it is well to conduct a series of tests. They will be performed on the sliding head and on the head support to ascertain if the alignment of each member is satisfactory when in actual working position. (Comparable tests will

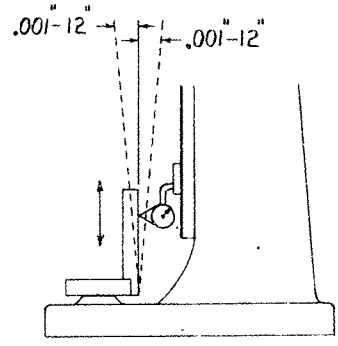

Fig. 28.35 Alignment tolerance for pedestal boss. Tolerance max. (±) .001" in 12" (Side view).

be executed subsequently on the knee member.)

Let us interject here that, although these tests are in a certain sense repetitious, they will be performed under different conditions which may, to a certain extent, affect the readings of the DIAL INDICATOR upon which we based our earlier decisions as to the validity of the several alignments. We are not trying to make these procedures unnecessarily complex or tedious, but it is essential to include every important step and point out all factors which tend to modify previously acceptable alignments or data. In other words, our aim is to suggest procedures whereby to detect here and now easily correctable faults which if not remedied at once can become a factor in Cumulative Error. (Refer to Sec. 23.16.)

Sec. 28.49
Tests of Sliding Head and Head Support with Column Erected

Four tests will be performed on the Sliding Head and Head Support to determine whether:

1. The guided slide of the sliding head is parallel with the spindle axis.
2. The guiding way of the head support is parallel with the guiding way of column.
3. The flat slides of the sliding head are parallel with the spindle axis.
4. The flat ways of the head support are parallel with the column face.

Sec. 28.50
Testing the Alignment of the Sliding Head

TEST NO. 1

Spindle to be parallel with the guiding way of the column.

PROCEDURE:

A test bar is inserted (See NOTE:) into the tapered hole in the spindle. The Surface Gage and attached DIAL INDICATOR are set on the flat ways of knee so that the plunger action of the button is parallel to the column face. The test bar is turned so that the mean position of eccentricity error makes contact with the DIAL button. Fig. 28.36 shows the set up required to determine the accuracy of alignment. The deflection of the pointer of the DIAL INDICATOR is noted as the knee is elevated. If the tolerance shown in Fig. 28.36b is exceeded, two possibilities suggest themselves, viz:

1. The guided slide of the sliding head may not be parallel to the axis of the spindle.
2. The guiding way of the head support may not be parallel with the guiding way of the column.

In the first case the alignment can be tested over again as indicated in Sec. 28.29. Since this operation involves removing the sliding head, it is advisable to conduct the following TEST NO. 2 before doing so. By this process of elimination we will decide which of the two possibilities is contributing towards the misalignment.

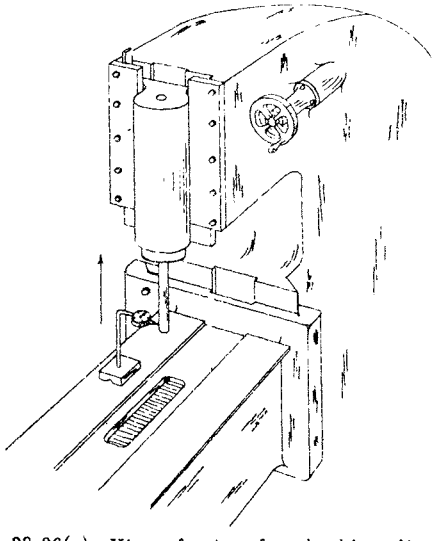

Fig. 28.36(a) View of set up for checking alignment of spindle to guiding way of column.

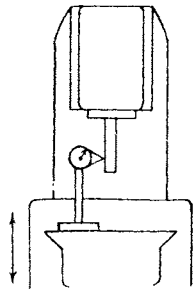

Fig. 28.36(b) Spindle parallel with guiding way of column. Tolerance max. .001" in 12". (Front view).

NOTE: It is standard practice whenever inserting a test bar to conduct a run out test immediately. This assures proper seating and truth in the alignment tests that follow:

Sec. 28.51
Testing the Alignment of the Sliding Head

TEST NO. 2

Sliding head movement to be parallel to the guiding way of the column.

PROCEDURE:

First, a stub arbor is inserted into the tapered hole of the spindle after which a DIAL INDICATOR is attached to it. Then a TOOL MAKER'S SQUARE is mounted and fastened as shown in Fig. 28.37. The button of the instrument is placed in contact with the blade of the SQUARE. (Plunger action of button should be parallel with the column face.) Using the hand wheel, the knee is elevated then lowered and simultaneously the beam of the SQUARE is shimmed until a precisely zero-zero reading is observed. When that condition is achieved it means that the blade of the SQUARE is exactly parallel with the guiding way of the column and consequently may be used as a check point for the sliding head. Incidentally, the accepted DIAL reading is always the one observed while the knee is moving upwards.

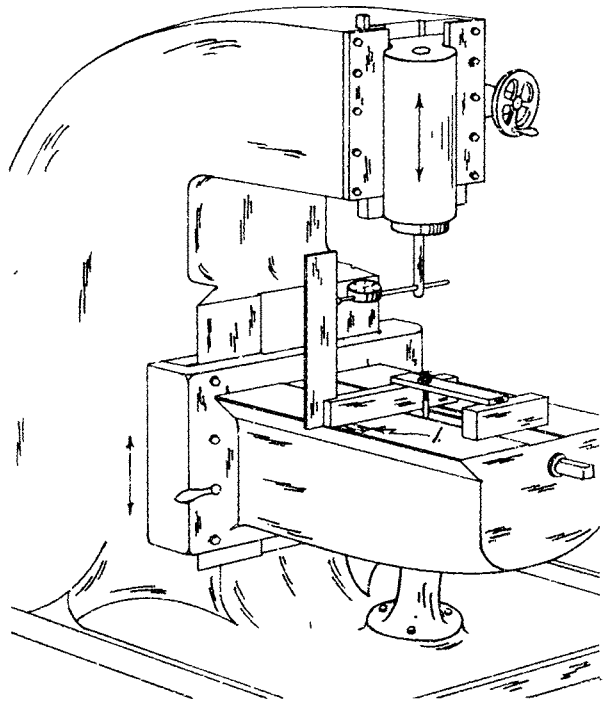

Fig. 28.37(a) General arrangement for checking sliding head movement to guiding way of column.

(1) shim stock.

To begin the second phase of the testing technique, the knee is raised sufficiently to remove all slack from the elevating mechanism. The member should not be locked. Now leaving the knee member alone momentarily, and without disturbing the button in contact with the blade, the sliding head is moved up and down. The reading on the DIAL will indicate the amount and direction of any deviation from parallelism in the guiding way of the head support with respect to the guiding way of the column. The error present should not exceed the tolerance shown in Fig. 28.37b.

After completing TESTS NO. 1 and NO. 2, we will know if either the guiding way of the head support or the guided slide of the sliding head, or both, contribute to the misalignment of the sliding head. Corrective measures must be undertaken where the need is indicated.

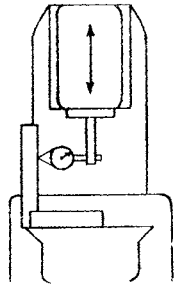

Fig. 28.37(b) Sliding head movement parallel with guiding way of column. Tolerance max. .0005" in 8" (Front view).

Sec. 28.52
Testing the Alignment of the Sliding Head

TEST NO. 3

The axis of the spindle to be parallel with the column face.

PROCEDURE:

In this test the set up is similar to that of TEST NO. 1. As Fig. 28.38a shows, the Surface Gage and attached DIAL INDICATOR are set on the flat ways of knee in such a way that the plunger action of the DIAL button is square with the column face. The test bar is revolved until the

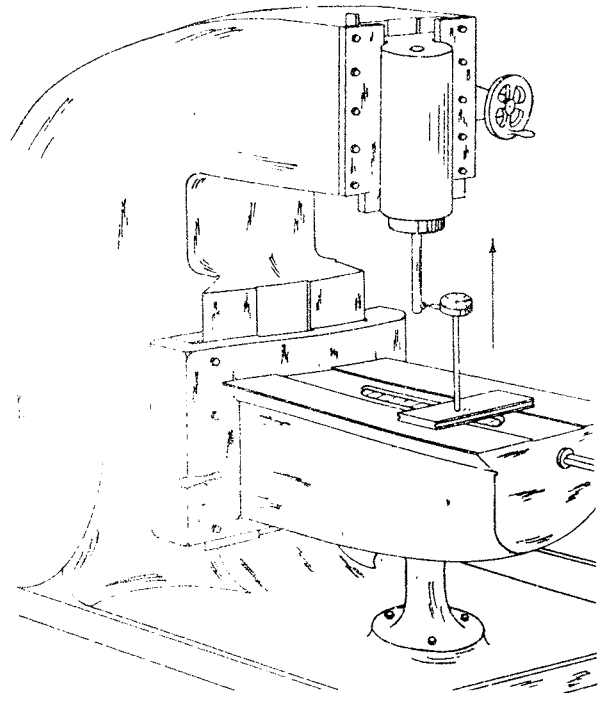

Fig. 28.38(a) Procedure for testing axis of spindle for parallelism with face of column.

mean position of eccentricity error is brought into contact with the button. By turning the hand wheel the knee is raised the maximum distance. This actuates the DIAL which registers the amount and direction of any deviation from parallelism.

If the tolerance shown in Fig. 28.38b is exceeded, then two possibilities suggest themselves, namely:

1. The flat slides of the sliding head may not be parallel to the axis of the spindle.

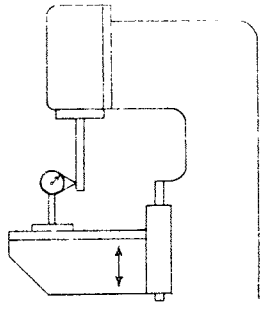

Fig. 28.38(b) Spindle parallel with column face. Tolerance max. .0005" in 6". (Side view).

This may be verified by the procedure in Sec. 28.27 "Back flat slides of the sliding head". Before doing so, however, we should investigate the other possibility, namely:

2. The flat ways of the Head Support may not be parallel with the column face.

This point may be established by executing TEST NO. 4 described as follows:

Sec. 28.53
Testing the Alignment of the Sliding Head

TEST NO. 4

Sliding Head Movement Parallel with Column Face.

PROCEDURE:

A bent rod is inserted into a collet in the tapered hole in the spindle. After mounting a DIAL INDICATOR on the rod, as shown in Fig. 28.39, the button is adjusted to touch the column face. The sliding head is moved upwards and downwards, and the reading of the instrument

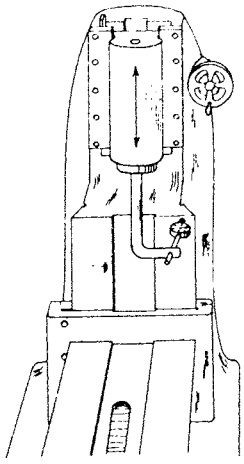

Fig. 28.39 Method of testing sliding head movement for parallelism with face of column.

is noted. The chief drawback of this method is in the somewhat flimsy set up due to the length and flexibility of the bent rod.

Fig. 28.40 shows a more substantial arrangement. A stub arbor is mounted in the spindle and a DIAL INDICATOR is suitably attached so that the plunger action of the button will be square with the column face. A SQUARE is placed on the knee flat way as shown. The beam of the SQUARE is shimmed until the DIAL whose button is in contact with the blade registers an absolute zero-zero reading while the knee is being elevated. When this reading is achieved, it signifies that the blade of the SQUARE is parallel to the column face. In consequence, it may now be used as a check point for the sliding head.

Without disturbing the existing set up, the sliding head is moved upwards and the reading observed. A tolerance is permitted as shown in Fig. 28.40b.

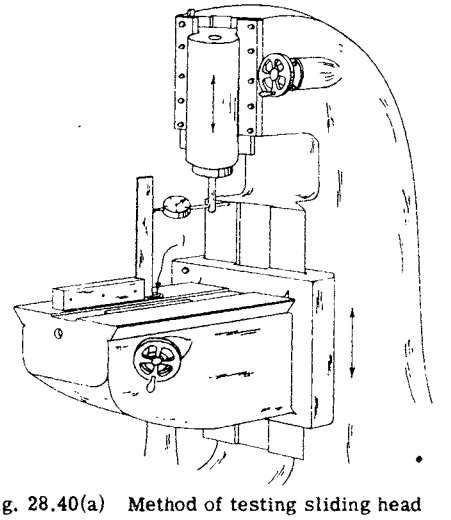

Fig. 28.40(a) Method of testing sliding head movement for parallelism with face of column.

(1) shims

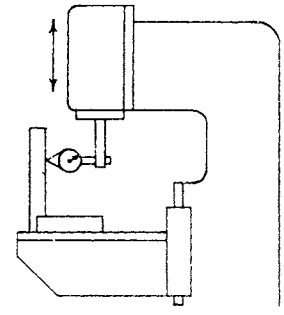

Fig. 28.40(b) Sliding head movement parallel with column face. Tolerance max. .0005" in 8". (Side view).

After executing TESTS NO. 3 and NO. 4, we will know if either the flat slides of the sliding head or the flat ways of the head support, or both, contribute to the misalignment of the sliding head. Corrective measures must be undertaken where indicated.

If the tolerance was not exceeded while executing ALIGNMENT TESTS NO. 1, 2, 3, and 4, we may consider the bearing surfaces associated with the sliding head as being satisfactorily completed.

Sec. 28.54
Preparations for Testing the Knee Under Working Conditions

We can now proceed to test the alignment of the knee member to the column. Three tests will be performed to determine whether:

1. The knee flat ways are square with the face of the column.
2. The flat ways of the knee are square with the guiding way of the column.
3. The guiding way of the knee is square with the column face.

Sec. 28.55
Testing the Alignment of the Knee

TEST NO. 1

Knee flat ways to be square with the column face.

PROCEDURE:

Fig. 28.41a shows the set up to be used. The SQUARE resting on PARALLELS is clamped to the knee while the DIAL INDICATOR is fastened to a fixture attached to the column as shown. In order to obtain dependable readings, all

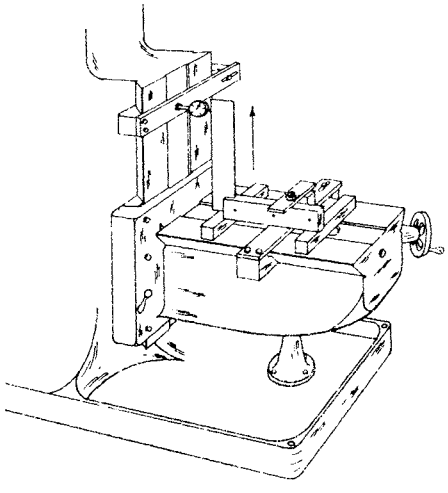

Fig. 28.41(a) Showing apparatus used to test the accuracy of alignment of the knee flat way to the face of the column.

slack is removed from the knee elevating mechanism by turning the handwheel a few revolutions to raise the member. After bringing the DIAL button in contact with the blade of the SQUARE, the reading is noted. Then the knee is elevated the maximum distance possible and the reading is again observed. Any change in the pointer will show the amount and the direction of the deviation from the specified alignment. In case the tolerance shown in Fig. 28.41b is exceeded, the knee flat ways must be rescraped to rectify the error. If a conscientious effort was exercised, in trying to align the knee flat way to the column face when the column was in the prone position, any present misalignment will be slight.

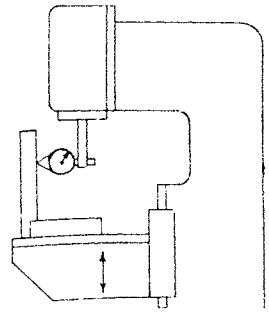

Fig. 28.41(b) Knee flat way square with column face. Tolerance max. .001" in 18" - Preferably low at back. (Side view).

Before any rectification is undertaken on the knee flat way, the test immediately following should be made, and if that tolerance is also exceeded, the surface is scraped to the resultant of the two errors. In other words, TESTS NO. 1 and NO. 2 are always conducted consecutively, and then the surface is treated.

Sec. 28.56
Testing the Alignment of the Knee

TEST NO. 2

Flat ways of the knee to be square with the guiding way of the column.

PROCEDURE:

Fig. 28.42a shows the set up used. It is similar to the one employed for the previous test. The practical details of this procedure are to remove all slack from the elevating mechanism by turning the hand wheel a few revolutions. The DIAL button is placed in contact with the blade of the SQUARE. Then a reading is taken at the starting point, and as the knee is cranked upwards, again at the stopping point.

If the tolerance allowed for this alignment is not exceeded, only the error discovered in TEST NO. 1 needs to be corrected. On the other hand, if alignment errors are found in both TESTS NO. 1 and NO. 2, they are combined in a resultant and the flat ways are scraped accordingly. When both tests can be executed without exceeding the tolerance shown in Fig. 28.41b and Fig. 28.41c, the flat ways are completed.

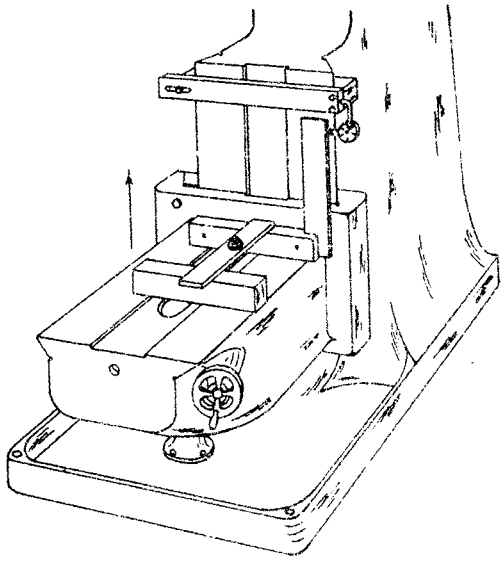

Fig. 28.42(a) Showing method employed to test the flat ways of knee for alignment with the guiding way of the column.

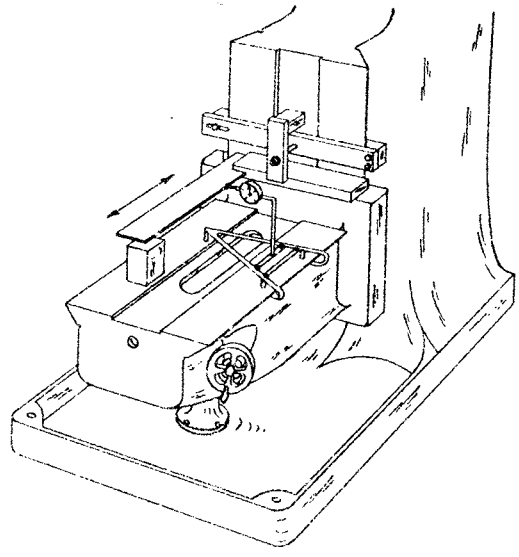

Fig. 28.43(a) Illustrating the set up employed to test the alignment existing between the knee guiding way and the face of the column.

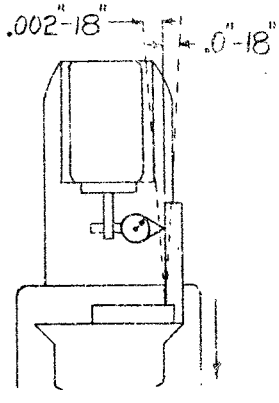

Fig. 28.42(b) Knee flat way square with guiding way of column.

Sec. 28.57
Testing the Alignment of the Knee

TEST NO. 3

Guiding way of the knee to be square with the column face.

PROCEDURE:

Fig. 28.43a represents the set up for the test. In this case the SQUARE is clamped to the column. A DIAL INDICATOR is mounted on an indicating jig in contact with the guiding way and the flat way of the knee. The block of steel shown in the figure is intended to support the blade of the SQUARE from sagging thereby preventing the DIAL button from running off the blade and registering falsely. The knee remains stationary throughout the test after the adjustment to remove slack in the elevating mechanism has been made.

To obtain a reading, the indicating device is moved from end to end of the blade. If the tolerance shown in Fig. 28.43b is exceeded, the guiding way must be rescraped to correct the error. The gib way, too, must then be dealt with to

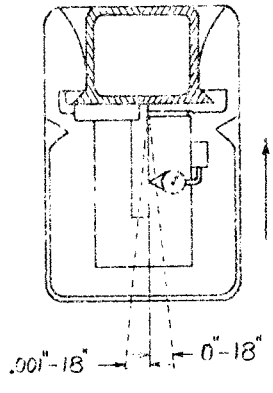

Fig. 28.43(b) Knee guiding way square with column face.

conform with the new alignment.

At this point it is well to sound a note of warning. Misalignment as indicated by this TEST NO. 3 is not the only reason why the guiding way (and gib way) might need to be rescraped. Much depends on what action was called for as a result of TESTS NO. 1 and NO. 2. For example, if misalignment was detected in the flat ways the relationship with respect to the angular ways is thus altered. This means that the angular ways must be rescraped if they are to have equal angles with respect to the flat ways which condition is often considered essential. The operation would be necessitated even if TEST NO. 3 showed that the alignment was within the tolerance.

This matter is brought to the operator's attention to emphasize once again the extreme care that must be exercised to attain all specified OBJECTIVES.

Sec. 28.58
The Plain Saddle

The saddle of the Vertical Milling Machine has a transverse movement on the ways of the knee. It has upper bearing surfaces which guide the table in longitudinal movement.

For convenience, the bearing surfaces of the plain saddle can be divided into two groups, viz:

The LOWER BEARING SURFACES
(Those associated with the knee)
- Flat Slides
- Guided Slide
- Gibbed Surface

The UPPER BEARING SURFACES
(Those associated with the table)
- Flat Ways
- Guiding Way
- Gibbed Surface

Which category should be dealt with first is determined by the results of the Exploratory Survey. It is usually advisable to start with the surfaces of that group showing the fewer signs of wear.

Since the treatment accorded the individual surfaces is similar, and the OBJECTIVES and Alignment Tests identical to those described previously in Sec. 27.46 of the Horizontal Milling Machine, it would be unduly repetitious to describe again.

Sec. 28.59
The Table

The table of the Vertical Milling Machine is a rectangular casting that is in sliding contact with the saddle. All milling machine tables are of the same general construction and are treated in a similar manner.

Scraping operations are confined to seven surfaces on the table. Usually the sequence of work is performed in the same order that the surfaces are enumerated, viz:

1. Top
2. Front
3. Back
4. Flat slides
5. Guided slide
6. Gib slide
7. End surfaces.

The treatment prescribed for the table member of the Vertical Milling Machine parallels that accorded the equivalent member on the Horizontal Milling Machine. Since there is no difference in the number of surfaces, or in the order of scraping them, and because the procedure is exactly the same, repetition will be avoided by simply referring the reader to the pertinent section in the Horizontal Milling Machine. (Sec. 27.82 through Sec. 27.92)

The manner of gibbing the table member does, of course, vary as between flat gibs and tapered gibs. However, numerous examples treating both kinds have been described and the reader should experience no difficulty on this score. In short, the scraping procedure, the required OBJECTIVES, and the number of surfaces are practically the same on all milling machine tables, regardless of type, make, or size.

Sec. 28.60
OBJECTIVES: The Tapered Gib Piece of the Table

1. Tapered side to be fitted to the gibbed surface of the saddle with a surface quality of 4-5 bearing spots per square inch.

2. The straight side to be fitted to the gib slide of the table with a surface quality of 10-15 bearing spots per square inch.

PROCEDURE:

The purely mechanical process of measuring and producing a tapered gib piece was discussed in Sec. 17.17 through Sec. 17.24. At this time we are more interested in the related operations attendant upon fitting a tapered gib to the table of a vertical milling machine. Primarily, these concern various tests for parallelism that hitherto could not be performed due to the unfinished condition of the members.

As we undertake the preparation of the tapered gib we must not commit the common mistake of being too hasty. The proper procedure is to scrape the piece until the correct taper is obtained, but to discontinue the operation before the bearing quality required by the OBJECTIVES is secured. This is considered good practice because alignment tests on the members sometimes disclose that the tolerance is exceeded. When the misalignment is corrected some alteration of the gib slot will be evident and the tapered gib piece will no longer fit properly when inserted. This is the reason a slower, more deliberate approach saves both time and effort in the long run.

Sec. 28.61
Testing the Table Slides for Parallelism

The following procedure can be performed most conveniently with the table resting top down on a work bench. After cleaning and oiling the slides of the table and the ways of the saddle, the two members are brought together. Then the tapered gib is inserted and adjusted for sliding pressure. The saddle is pushed from end to end of the table, meanwhile testing for slack and bind enroute. (See Sliding Member Test Sec. 22.11) The saddle should also be given the Shake Test (Sec. 22.5)

If non-parallelism of the table slides is discovered this condition must be corrected immediately. Not until parallelism is established in the slides of the table, and a proper fit assured between these surfaces and the ways of the saddle, should the table gib piece be scraped to the required surface bearing quality.

Sec. 28.62
Static Alignment Tests

All members of the Vertical Milling Machine having been scraped, it is now advisable to ascertain whether the numerous alignment tests performed on each member individually, as well as on the various sub-assemblies, were accurately executed. To this end, a series of final tests, static in nature, will be undertaken. They are arranged in the order they should be made, which is the approximate sequence the members were originally scraped.

Some of the tests that follow were conducted previously during scraping operations. Others are quite different. In all cases diagrams accompany the TEST to assist comprehension.

Realizing that during the long course of scraping imperfections sometimes develop, which may escape immediate detection but are revealed by the final Static Alignment Tests, the author has included suggestions as to probable sources of error when a particular tolerance is exceeded.

In general preparation for the Static Alignment Tests, the several members are thoroughly cleaned. Following this the bearing surfaces are lightly oiled. All members are assembled, and gibs are inserted and adjusted for sliding pressure.

When assembling the machine only the essential parts are attached. Oiling pads, felt and metal wipers, guards, etc., are superfluous at this time. Taper pins holding the handles and handwheels to the feedscrews can be tapped in but should not be filed off flush. Observing these pointers saves considerable time should the machine have to be dismantled again for any reason.

It is always good practice to run in the machine under power for about one hour. During this warming-up period the various members are repeatedly inspected for quietness and smoothness of movement. When the machine attains a constant, normal, operating temperature the Final Static Alignment Tests may be performed.

CAUTION: The precision of the DIAL INDICATOR used should be at least equal to the accuracy demanded in the Alignment Tests.

Sec. 28.63
STATIC ALIGNMENT TEST NO. 1

Leveling the Vertical Milling Machine

PROCEDURE:

The vertical milling machine is leveled by placing a PRECISION LEVEL on the work table at positions (A) and (B) as shown in Fig. 28.44.

(A) Work table flat or level in longitudinal direction. Tolerance .0005" in 12".
(B) Ditto in transverse direction, Tolerance .0005" in 12".

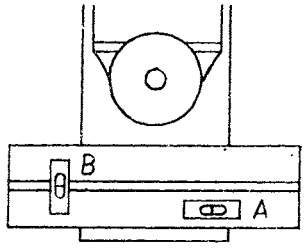

Fig. 28.44 Leveling the table in (A) longitudinal and (B) transverse directions. Tolerance in either direction max. .0005" per foot.

Sec. 28.64
STATIC ALIGNMENT TEST NO. 2

Movement of Members when Clamp Is Locked

PROCEDURE:

This test should be performed consecutively on the knee, the saddle, the table, and the sliding head. It has a three-fold purpose. First, to provide further assurances that the ways of the several members are flat and parallel. Second, to certify that the slides are well fitted to their ways. Third, to make certain that the gib pieces are scraped to the correct taper, i.e., well fitted.

The physical set-up need not be elaborate. A DIAL INDICATOR attached to a Surface Gage is placed on the table top as shown in Fig. 28.45. The Button of the instrument must always be so located that the maximum displacement will be registered if the member shifts. In other words, contact should be made against a solid surface that will not be affected when the hand clamps on the various members are locked. Such a surface could be the column face, or a stub arbor inserted into the tapered hole of spindle.

Assuming that we wish first of all to test the knee member, it is unlocked. Meanwhile, precautions are taken that the saddle and the table are securely clamped. Close attention is given to the DIAL pointer, both before and after, the hand clamp is tightened locking the knee to the column.

If the error disclosed exceeds the tolerance shown in the Figure mentioned above, it may be necessary to conduct extensive testing of the slides of the knee and the gib to locate the source of error. It is extremely difficult to assign the cause of trouble to any particular surface without dismantling the machine and testing each surface for flatness, parallelism, or fit, as the case may be. Possibly, the fault may be situated in more than one surface.

Fundamentally, the origin of the trouble lies in being too easily satisfied with each individual surface as it is scraped and accepted. It is preferable to be a little more exacting in one's work and thereby provide a larger margin of safety for the final Static Alignment Tests. Obviously, considerable work will be involved if the

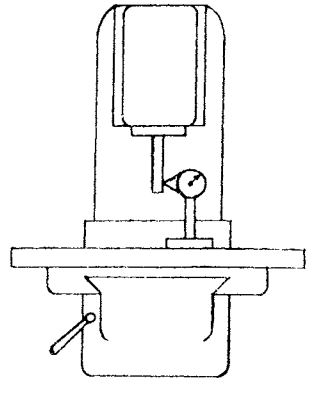

Fig. 28.45 Movement of member when clamp is locked. Tolerance max. .001" knee, .001" saddle, .001" table, .0002" sliding head.

machine, at this late date, must be dismantled to have a surface rescraped. Furthermore, there is the possibility that rectification of the immediate error could throw another member out of alignment.

The procedure is concluded by testing the saddle, table, and sliding head in exactly the same manner.

Sec. 28.65
STATIC ALIGNMENT TEST NO. 3

Spindle End Periphery and Face Run Out

PROCEDURE:

This operation tests the eccentricity of the spindle and spindle tapered hole with respect to the axis of revolution. Also it will indicate the cylindricity, or roundness, of these two surfaces.

To conduct the test for Spindle End Periphery, a DIAL INDICATOR is attached directly to the table, or fastened to a heavy weighted Surface Gage, placed on the table. The DIAL button is positioned first at the periphery of the spindle end, or just inside the tapered hole, or at both places consecutively. See Fig. 28.46a)

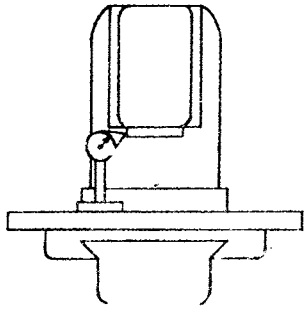

Fig. 28.46(a) Spindle End Periphery run out. Tolerance max. .0002".

The Face Run Out will test the spindle for cam action. It is performed by placing the DIAL INDICATOR button on the face of the spindle. (See Fig. 28.46b)

For either set up the spindle is rotated at slow speed while the reading is noted. Should the tolerance shown in the figure mentioned be exceeded in any of these positions, it would indicate that either the spindle, or the spindle bearings need attention.

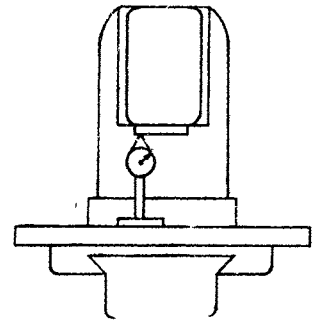

Fig. 28.46(b) Spindle Face run out. Tolerance max. .0002".

Such a fault could be quite serious inasmuch as the spindle was used as a check point while scraping the bearing surfaces of the sliding head. Hence it is entirely possible that the alignment of the slides to the axis of the spindle is not correct. If the above tests have been conducted carefully, as recommended previously in Sec. 28.26, a major error would not now be a probability. Besides correcting the error in the spindle, or spindle bearings, treatment may involve rescraping one or more of the slides of the sliding head. However, before removing the member to effect repairs, the following test should be performed, namely Test No. 4.

Sec. 28.66
STATIC ALIGNMENT TEST NO. 4

Spindle Run Out

PROCEDURE:

This test determines two possible conditions of the tapered spindle hole, viz:

1. The inclination of the axis of the tapered hole to the axis of rotation of the spindle.
2. The eccentricity of the axis of the tapered hole with respect to the axis of rotation of the spindle.

To perform this check a test bar is inserted into the spindle. After mounting a DIAL INDICATOR on the table, the DIAL button is placed in contact with the test bar, first near the spindle end, and then by lowering the table, at the free end of

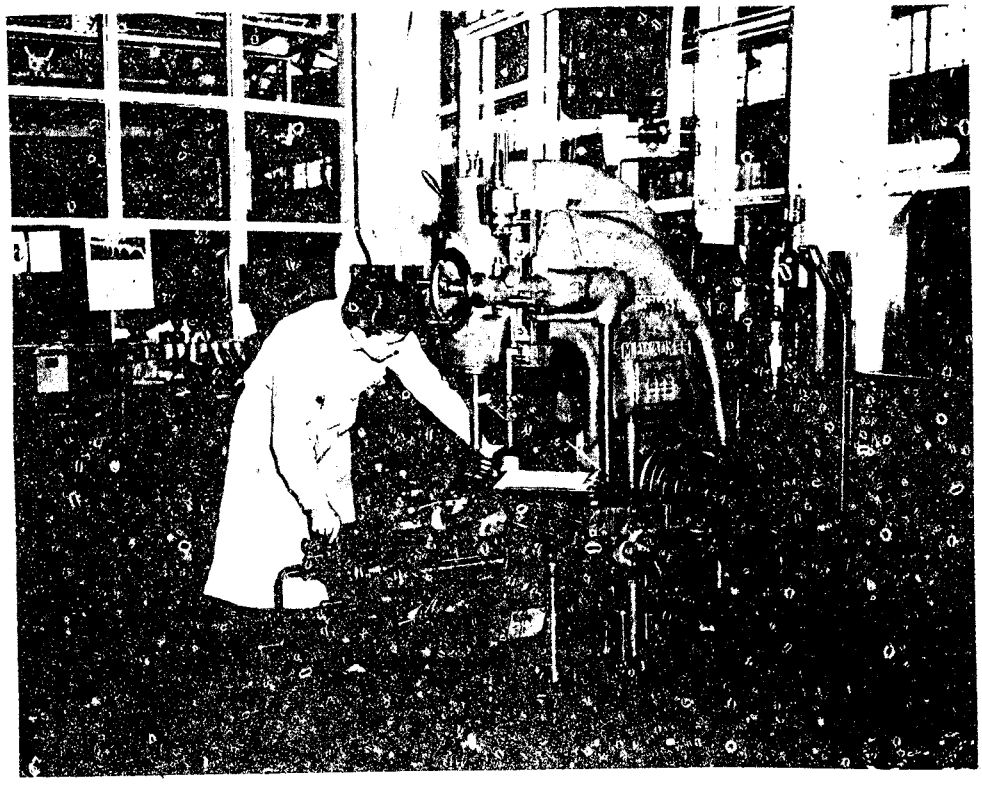

PLATE 55. Checking spindle run out on Vertical milling machine. (Courtesy - Kearney & Trecker Corp.)

the bar. The spindle is slowly rotated, meanwhile scanning the DIAL. If the tolerance shown in Fig. 28.47 is exceeded, it is possible, as in Test No. 3, for the sliding head to be misaligned because the check point, i.e., the spindle was imperfect.

We repeat and add emphasis to our previous warning that it is essential for this test to be performed accurately when first undertaken, as discussed in Sec. 28.26. The spindle must be removed and the fault corrected before proceeding with the remainder of the Static Tests.

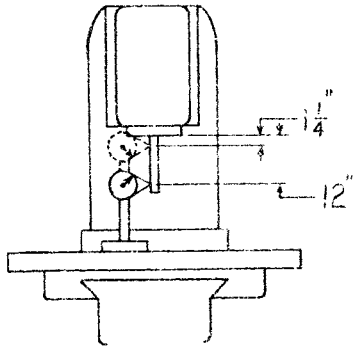

Fig. 28.47 Spindle run out. Tolerance max. 1 1/4' from end of spindle .0005" , 12" from end of spindle .001".

Sec. 28.67
STATIC ALIGNMENT TEST NO. 5

Sliding Head Movement Parallel with the Guiding Way of the Column

PROCEDURE:

Probably the more accurate method of conducting this test is with the aid of a special precision scraped jig, as shown in Fig. 28.48. The jig mentioned is utilized by manufacturers in performing this particular test. It is designed to be clamped to the guiding way of the column. A DIAL INDICATOR, suspended from the spindle and engaging the jig, will check the alignment of the sliding head as the member is raised and lowered.

However, because of the work involved, it is unlikely that the operator will take

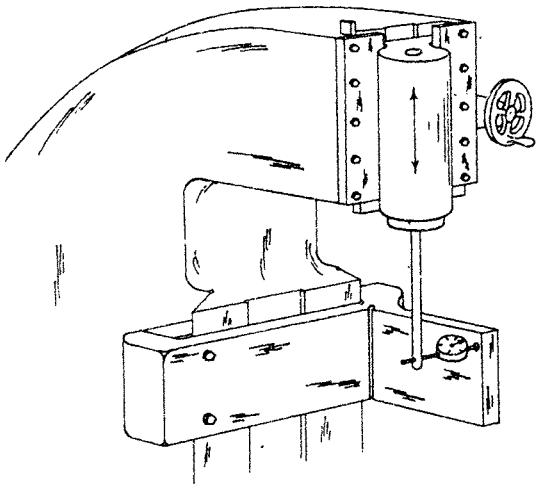

Fig. 28.48 Special jig for testing sliding head movement for parallelism with guiding way of column.

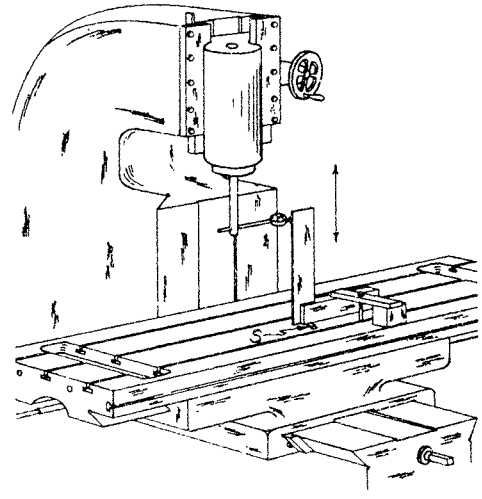

Fig. 28.49(a) Using a Try Square for testing parallelism of guiding way of sliding head with guiding way of column.

(S) shims

the trouble to make up such a device for an average reconditioning job. Consequently, an alternative method, widely favored because it can be executed with standard tools, will be discussed instead. The operator, undoubtedly, will be familiar with it, as it was described previously in Sec. 28.50. Therefore, for the sake of brevity, only the chief points will be touched on.

After inserting a stub arbor into the tapered hole in the spindle, a DIAL INDICATOR is attached thereto. A MASTER SQUARE is positioned on the table top with provision made for clamping it, as shown in Fig. 28.49a. The DIAL INDICATOR button is adjusted to touch the blade of the SQUARE. As the knee is raised, the reading of the DIAL is noted. The SQUARE is shimmed if necessary until an exact zero-zero calibration is secured. When this condition exists, the blade of the SQUARE is parallel with the column guiding way and may be employed as a check point to test the alignment of the sliding head. At this juncture the knee should not be locked, as this action may throw the knee and hence the SQUARE out of the delicate adjustment just accomplished.

Without disturbing the DIAL button which is still in contact with the blade of the SQUARE, the sliding head is raised its full limit of movement. Correct alignment is indicated if the DIAL registers an absolute zero-zero reading, although a small bi-lateral tolerance is permitted, as shown in Fig. 28.49b.

Should the tolerance be surpassed, the guiding way of the head support must be rescraped after removing the sliding head. This may necessitate refitting the tapered gib. Had the alignment test been performed properly, as discussed in Sec. 28.51, this repetitious operation would not now be necessary.

The following test, NO. 6, should be conducted consecutively with TEST NO. 5.

CAUTION: Instead of a bi-lateral tolerance, a unilateral tolerance is

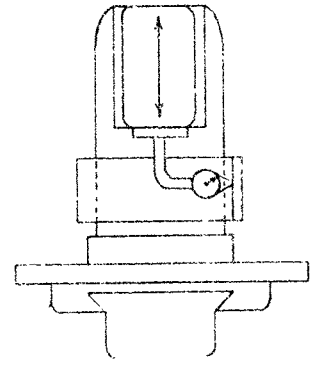

Fig. 28.49(b) Sliding head movement parallel with guiding way of column. Tolerance max. .0005" in 8"

sometimes given in the Manufacturer's Test Record Card. In such a case, the operator must reconcile a number of factors. The direction of movement of the sliding head, the position of the SQUARE, which side of the blade is in contact with the DIAL button, all need to be taken into account in determining whether the unilateral tolerance is exceeded.

Sec. 28.68
STATIC ALIGNMENT TEST NO. 6

Sliding Head Movement Parallel with the Column Face

PROCEDURE:

If desired, the operator may perform this alignment test by utilizing the MASTER SQUARE procedure, as discussed in the previous test, NO. 5. The set up must, of course, be altered to adapt it to test against the column face.

The sliding head is moved and the position of the DIAL pointer is noted at the start and finish of the movement. The difference between the two readings will determine if the permissible tolerance shown in Fig. 28.50 has been exceeded.

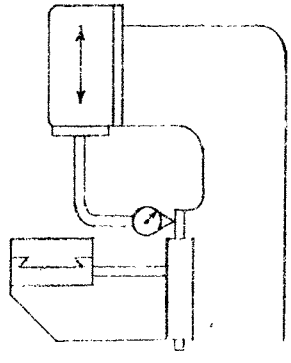

Fig. 28.50 Sliding head movement parallel with column face. Tolerance max. .0005" in 8".

If the misalignment is excessive, the flat ways of the head support must be rescraped to a correct alignment. Furthermore, the gib bracket bearings must also be rescraped to provide the necessary working clearance. This error should have been noted when testing these surfaces as discussed in Sec. 28.53.

Static TESTS NO. 5 and NO. 6 are conducted consecutively, before initiating corrective scraping on the surfaces concerned.

Sec. 28.69
STATIC ALIGNMENT TEST NO. 7

Spindle Parallel with the Guiding Way of the Column

PROCEDURE:

A DIAL INDICATOR is secured to the table by any convenient means, and a test bar is inserted in the tapered hole of the spindle. The test bar is revolved until the mean position of eccentricity error is found. Then the button of the instrument is brought into contact with the mean position of the test bar at the proper side, as shown in Fig. 28.51a.

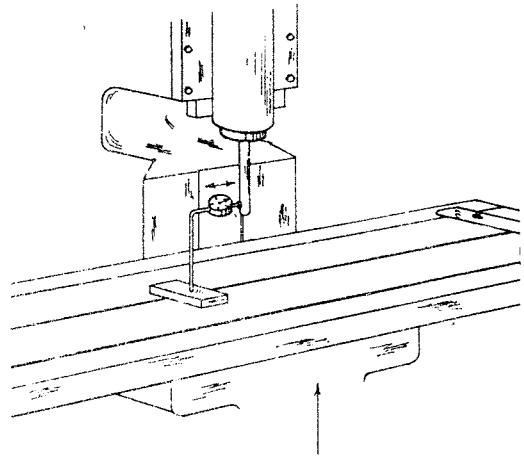

Fig. 28.51(a) General arrangement for testing spindle for parallelism with respect to guiding way of column. (Double headed arrow indicates required direction of plunger movement of DIAL INDICATOR).

One or two complete revolutions of the knee elevating screw are made with the hand wheel to remove slack, and then the position of the DIAL pointer is noted. Next the knee is elevated as far as the test bar permits at which point the reading is again observed. The difference between the two readings must not exceed the tolerance shown in Fig. 28.51b.

If the tolerance is exceeded, the results of TEST NO. 7 are open to two interpretations. First, the guiding way of

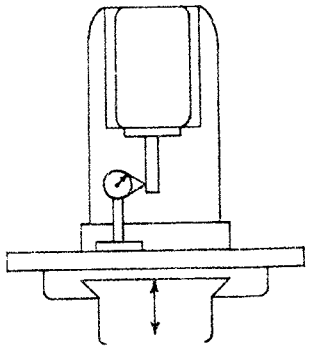

Fig. 28.51(b) Spindle parallel with guiding way of column. Tolerance max. .001" in 12".

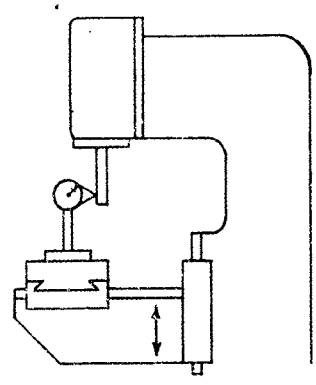

Fig. 28.52 Spindle parallel with column face. Tolerance max. .0005" in 6".

the head support is not properly aligned with the guiding way of the column. Second, the guided slide of the sliding head is not properly aligned with the axis of the spindle.

The first possibility may be discarded if we have performed TEST NO. 5 and passed it successfully. By this process of elimination, the alternative may be assumed to be the source of error. This error is due to an inadequate effort in the initial treatment of this surface discussed in Sec. 28.29.

In other words, the guided slide of the sliding head must be rescraped to a correct alignment with the axis of the spindle. Coincident with this, the gib slide must be scraped parallel to the guided slide. (The gib piece will also need to be corrected.) Before removing the member to undertake this work, it is advisable to perform the following related TEST NO. 8.

Sec. 28.70
STATIC ALIGNMENT TEST NO. 8

Spindle Parallel with the Column Face

PROCEDURE:

A test bar is inserted into the tapered hole of the spindle and tested for run out. This proves the bar is correctly inserted. When the mean position of eccentricity error is located, the test bar is turned until this position is toward the front of the machine, i.e., opposite the column face. A DIAL INDICATOR is mounted securely on the table top after which the button is brought into contact with the bar at the mean position, as indicated by Fig. 28.52.

The knee member is lowered as far as possible, then elevated slightly with one or two turns of the hand wheel to remove all lost motion. At this point, the position of the DIAL pointer is observed. Next the knee is raised to the maximum height permitted by the test bar whereupon another reading is taken. If the two readings disclose a difference over and above the tolerance shown in the figure, the alignment is not acceptable.

Either of two factors may be the cause of the misalignment, to wit:

1. The flat ways of the head support are not parallel with the column face. This possibility is eliminated if TEST NO. 6 has been successfully passed. In that case the alternative must be investigated, namely:
2. The flat slides of the sliding head are not parallel to the spindle axis. The error can be corrected by rescraping the flat slides of the sliding head to align them with the axis of the spindle, as suggested in Sec. 28.52, Additionally, it will be necessary to rescrape the gib bracket bearings of the head support to provide proper working clearance.

Sec. 28.71
STATIC ALIGNMENT TEST NO. 9

Table Top Square with the Spindle (Front and Rear)

PROCEDURE:

After centrally positioning the table under the spindle, and inserting a stub arbor, a DIAL INDICATOR is attached thereto. The button of the DIAL is adjusted to touch the top of the table, or,

preferably, a hardened steel test plate is interposed. (Sec. 8.7 Hardened Steel Plates.)

Utilizing the swing round method, we test front and rear for a unilateral tolerance, as shown in Fig. 28.53. Should the tolerance be exceeded, several possibilities suggest themselves, viz:

1. The knee flat ways are not square with the column face. To eliminate this possibility, the test outlined in Sec. 28.55 can be adopted.
2. The flat slides and flat ways of the saddle are not parallel (measured transversely). A pertinent test to apply is described in Sec. 27.52. (Horizontal Milling Machine)
3. The flat slides and the top of the table are not parallel. The appropriate test of this condition is discussed in Sec. 27.87. (Horizontal Milling Machine)

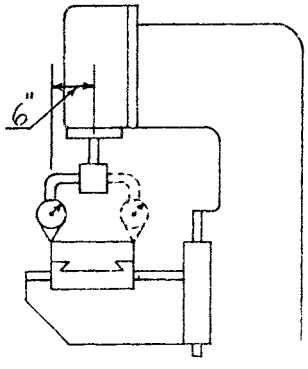

Fig. 28.53 Table top square with spindle. (Front and rear) Tolerance max. .001" in 12", preferably low at back.

One or more of these alternatives may be the cause of the misalignment. To narrow it down proceed as follows:

One member at a time is removed while the remaining members are tested. Thus if the table is found to be accurate, it is set to one side. Then the ways of the saddle are tested to learn whether they are square with the column face. If the error is still present, the flat ways of the knee are tested. By this process of elimination, the source of the misalignment of a particular machine can be located. Test NO. 10 should be made concurrently.

Sec. 28.72
STATIC ALIGNMENT TEST NO. 10

Table Top Square with the Spindle (Right and Left)

PROCEDURE:

The same equipment used in Test No. 9 is employed for this test. The swing-round method is utilized to determine if the tolerance indicated in Fig. 28.54 is exceeded. With the table centrally located, longitudinally and transversely, under the spindle, measurements at right and left are taken. A zero-zero reading is desirable although a small tolerance is permissible.

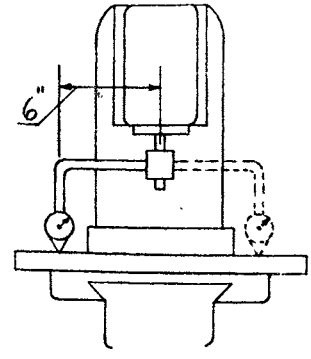

Fig. 28.54 Table top square with spindle. (Right and left) Tolerance max. .001" in 18".

Should a misalignment be disclosed, several possibilities suggest themselves. For example:

1. The flat ways of knee are not square with the column guiding way. An appropriate test for this is outlined in Sec. 28.56.
2. The flat slide and flat ways of the saddle (measured longitudinally) are not parallel. This possibility can be checked as described in Sec. 27.52. (Horizontal Milling Machine)
3. The flat slides and top of the table are not parallel. This likelihood results from negligent execution of the procedure discussed in Sec. 27.87. (Horizontal Milling Machine)

When the tolerance is exceeded, it is possible to find the faulty member, or members, by a process of elimination. This is accomplished by removing one

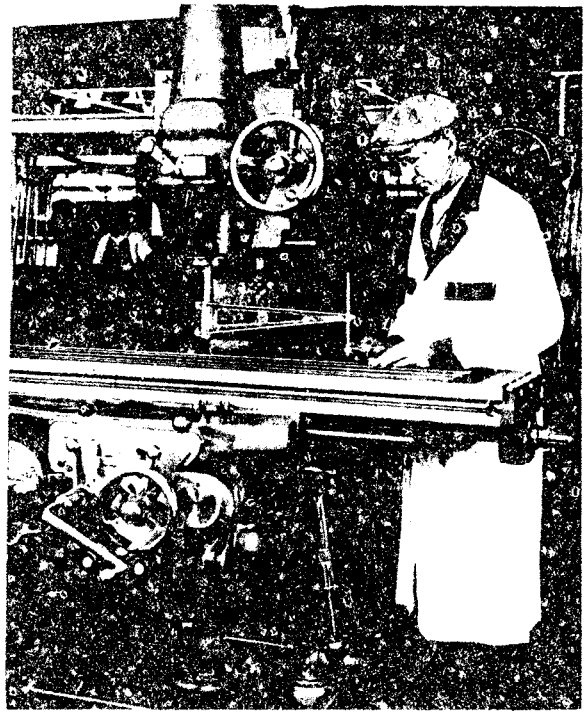

PLATE 56. Testing alignment of table top square with spindle (right and left) of Vertical milling machine. Note the hardened steel testing block under button of DIAL INDICATOR. (Courtesy - Kearney & Trecker Corp.)

component at a time, starting with the table, and testing from the top-most surface of the next member below, and so on. Tests NO. 9 and NO. 10 should be performed together.

Incidentally, the 3rd point mentioned above may be checked by an alternative method without removing the table. It is discussed in the next test, NO. 11.

Sec. 28.73
STATIC ALIGNMENT TEST NO. 11

Rise and Fall of Table in Longitudinal Movement

PROCEDURE:

A stub arbor is inserted into the spindle and a DIAL INDICATOR is attached. The DIAL button is adjusted to rest on the table top. The table is moved longitudinally the maximum distance beneath the DIAL button while the reading is observed. Fig. 28.55 shows the allowed tolerance. If exceeded, it signifies that the table flat slides were not scraped parallel with the table top (measured in the longitudinal direction.) The error in this instance can lie only in the table member.

Before removing the table to correct this misalignment, TEST NO. 12 should be conducted. This is advisable so that in case an error is disclosed, attributed to the flat slides not being parallel as measured in the transverse direction to the top of table, they may be rescraped to a resultant of both tests.

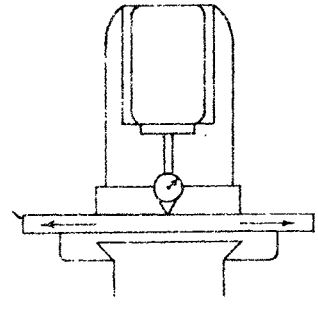

Fig. 28.55 Rise and fall of table in longitudinal movement. Tolerance max. .0005" in 24".

Sec. 28.74
STATIC ALIGNMENT TEST NO. 12

Rise and Fall of Table in Cross Movement

PROCEDURE:

A stub arbor is inserted into the spindle and a DIAL INDICATOR is attached. The button of the DIAL, as in the previous test, touches the table top, as represented in Fig. 28.56. By moving the table transversely towards the column, the DIAL is actuated.

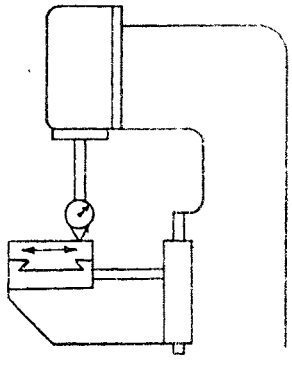

Fig. 28.56 Rise and fall of table in cross movement. Tolerance max. .001" in 12".

Incidentally, only sufficient pressure should be applied to the DIAL mechanism to obtain a reading. This precaution has for its purpose the protection of the delicate works of the instrument from shock damage as the button drops into the T-slots passing beneath. If instead of positioning the DIAL button directly upon the top of table, a steel PARALLEL is interposed, this danger is eliminated.

In case the tolerance is exceeded, it denotes that the table flat slides were not scraped parallel with the table top as required by the OBJECTIVES given in Sec. 27.87 (measuring transversely.) To correct the misalignment it will be necessary to remove the table and rescrape the flat slides.

This procedure presupposes that any lack of parallelism is exclusively the fault of the table. But we should not lose sight of the fact that the fault now discernible, may have had its inception when the saddle was dealt with. For example, the scraping tolerance of the saddle may have been exceeded. In such cases, the table would not be responsible for the present difficulty, or only partly so. To discover the origin of the misalignment it will be necessary to remove the table then repeat the test on the flat ways of the saddle. Usually no one member is wholly responsible but rather each contributes something to the deficiency.

Sec. 28.75
STATIC ALIGNMENT TEST NO. 13

Center T-Slot Parallel with Table Movement

PROCEDURE:

A stub arbor is inserted into the spindle and a DIAL INDICATOR is attached. The button of the DIAL is positioned against one side of the throat of the T-slot. After moving the table the maximum distance, longitudinally, any change in the reading is noted. This operation is then repeated with the DIAL button in contact with the other side of the throat. Should the tolerance shown in Fig. 28.57 be exceeded in either case it signifies that the guided slide of the table was not scraped parallel with the center T-slot as required by the OBJECTIVES in Sec. 27.88 (Table of Horizontal Milling Machine).

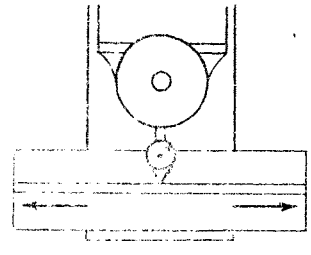

Fig. 28.57 Center T-slot parallel with table movement. Tolerance max. .001" in 18".

Since the center T-slot was selected as the check point for various surfaces of the table member, as discussed in Sec. 27.83, it will be necessary to remove the table and rescrape the angular guided slide to correct this misalignment. As a consequence, the angular gibbed slide of the table must also be rescraped parallel with the guided slide. Furthermore, the gib piece may need to be refitted, provided templates were not used to obtain a definite angular value for the gibbed slide.

Sec. 28.76
STATIC ALIGNMENT TEST NO. 14

Center T-Slot Square with Cross Movement

PROCEDURE:

A SQUARE is laid horizontally on the table top with the blade approximately parallel to the center T-slot as shown in Fig. 28.58. It is clamped lightly. A Surface Gage is positioned in the center T-slot. Next the DIAL button is set against the blade of the SQUARE. As the Gage is slid along the T-slot, the SQUARE is trued until the DIAL reading is exactly zero-zero from end to end of the blade. The blade of the SQUARE will now be parallel with the center T-slot, and it should be immovably clamped in this position.

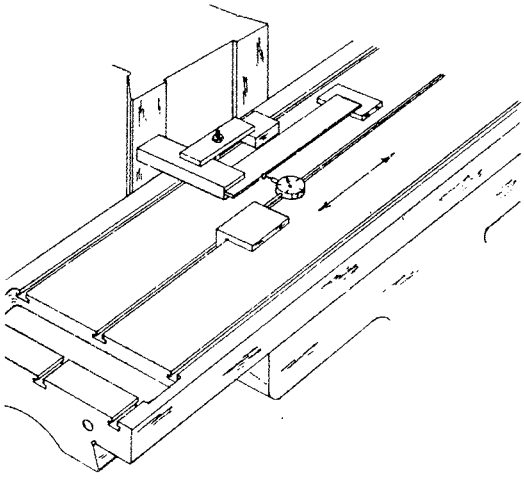

Fig. 28.58 View showing method of arranging set up for testing center T-slot in cross movement.

It is necessary at this point to insert a stub arbor into the spindle and attach the DIAL to it. Fig. 28.59a shows how the button of the DIAL is positioned against the beam of the SQUARE. The table is moved transversely and the reading of the instrument is noted.

If the tolerance shown in Fig. 28.59b is exceeded, the misalignment can be corrected by rescraping the guided slide of the saddle. The usual alterations to the gibbed surface and gib piece will, of course, be required.

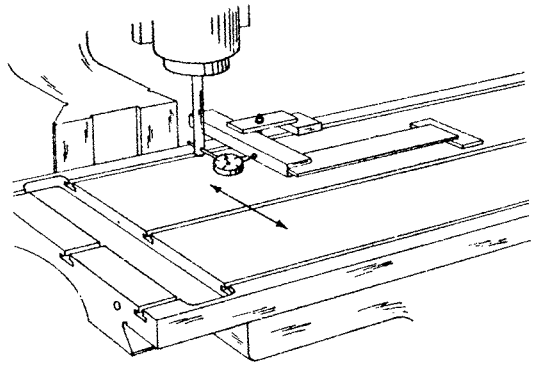

Fig. 28.59(a) Testing T-slot square with cross movement.

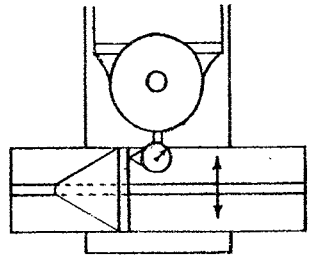

Fig. 28.59(b) Center T-slot square with cross movement. Tolerance max. .001" in 12".

Sec. 28.77
ALIGNMENT TEST NO. 15

T-slots Square with Top of Table

PROCEDURE:

The set up for this test is described in detail in Sec. 27.84 (Table Top of the Horizontal Milling Machine).

Since the procedure is exactly the same and since Fig. 28.60 is practically self-explanatory, we shall not discuss this test further.

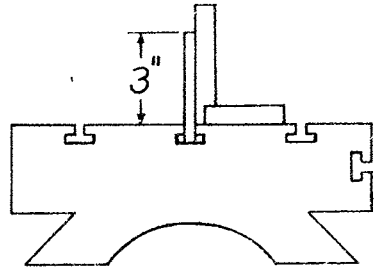

Fig. 28.60 T-slots square with top of table. Tolerance max. .001" in 3".

Sec. 28.78
STATIC ALIGNMENT TEST NO. 16

Back Lash in Lead Screws

PROCEDURE:

1. The permissible back lash. This is noted on the DIAL as the hand wheel or the feed screw is oscillated the maximum possible but without moving the member being tested. Tolerance is represented in Fig. 28.61a.

Fig. 28.61(a) Back Lash in Lead Screws. Read on Dials.

	max. tolerance
Table screw	.005"
Cross Feed screw	.005"
Vertical Feed screw	.008"
Sliding Head screw	.005"

2. The maximum error in total length. Considerable testing equipment of a special nature would be necessary for this set up. Furthermore, since the information obtained would be of interest to only a few, space devoted to this subject would hardly be justified. Tolerance is shown in Fig. 28.61b.

Fig. 28.61(b) Maximum Error in Total Length

	max. in 12"	in total length
Table screw	(±) .001"	(+) .002" (-) .001"
Cross Feed screw	(±) .001"	(+) .002" (-) .001"
Vertical Feed screw	(±) .001"	(+) .002" (-) .001"
Sliding Head screw	(±) .001"	(+) .002" (-) .001"

This completes the STATIC ALIGNMENT TESTS on the Vertical Milling Machine. Essentially, we have ascertained the degree of accuracy with which the machine is assembled. All measurements have been made with the machine idle and in the unloaded condition.

Performance tests involving working tolerances are not within the scope of this book. Many factors influence the grade of working accuracy, besides the condition of the bearing surfaces themselves. If the scraping operator has not exceeded the tolerances allotted to him, he may be reasonably confident that he has discharged his share of responsibility in the work of reconditioning a vertical milling machine. However, many operators will wish to test the completed machine under operating conditions. For specific standards, the Manufacturer's Test Record Card is recommended.

Chapter 29

PRECISION GRINDING MACHINES
THE CYLINDRICAL GRINDER

Precision grinding machines are a class of machine tool designed to give a very smooth finish to ordinary machined surfaces. When lathes, millers, shapers etc. machine metal surfaces, they produce apparently smooth finishes which suffice for many purposes. However smooth the finishes may appear to the eye, an examination under a microscope plainly reveals numerous ridges and furrows. To further smooth out the small irregularities which are formed, PRECISION GRINDING MACHINES are used. Producing work pieces of accurate dimension, rapidly, and at economical cost is another and equally important reason for the popularity of precision grinders.

The principal parts of a precision grinder comprise a massive bed, a wheel head, a revolving wheel spindle on which the grinding wheel is mounted, and a work table.

Grinding machines are made for a wide variety of purposes, and to perform these jobs, each classification of grinder is provided with diverse movements. For example, the wheel and its spindle revolve independently of the work, and the wheel head may be controlled by a traverse feed, and in-feed, or both, depending on the type of machine.

Tables are of two classes; reciprocating tables, which draw the metal piece back and forth across the face or flank of the revolving wheel; and revolving tables, which carry the metal piece under the abrasive wheel. To facilitate grinding, tables may be equipped with a transverse feed, and in-feed, a vertical feed, or all three.

To actuate the various parts, mechanical, hydraulic, or electrical means are employed.

In all types of grinders, provision is made for selective changes of cutting speed (peripheral speed of grinding wheel), work speed (peripheral speed of work), rate of table traverse (sweep of grinding wheel across the face of the work), and rate of wheel in-feed (depth of metal removed).

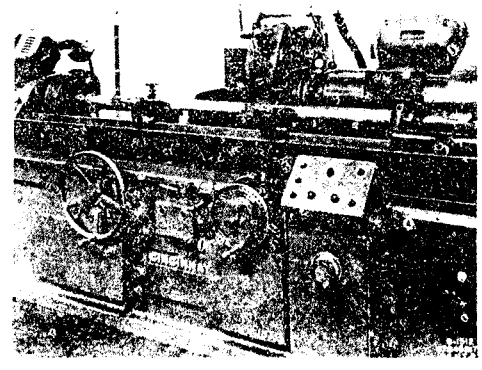

PLATE 57. Front view of cylindrical grinder grinding a piece of work between centers. Note form of guiding way of swivel plate. (Courtesy - Cincinnati Grinders, Incorporated.)

The bearing surfaces on which the various components slide vary widely in shape according to the special operations the machine must perform or the preference of individual designers. Horizontal reciprocating tables may ride on double V's, inverted V's, opposed V's, or one V-way and one flat way.

Positioning of foot stock, workhead, journal rests etc. is accomplished by means of dovetails, an inclined V-and flat way, or a flat way and T-slot. The particular angles these ways possess varies considerably.

Another method of providing movement is by mounting the work table on balls or rollers running in hardened and ground ways. This system eliminates all

traces of irregular table motion and is required for machines such as thread grinders or roll grinders. The wheel head slides and dressing tool slides of thread grinders may also be mounted on rollers.

On some machines the rollers bear directly on cast iron surfaces. On other machines, the rollers bear against hardened, steel inserts, fastened to the iron surfaces. These surfaces must always be scraped flat and true upon reconditioning if the slightest warp is present. New and straight inserts are then attached.

Circular ways designed to carry the load of horizontal rotary tables are also made. These ways are usually flat since the alignment of the table is controlled by a central spindle.

The kinds of jobs performed on precision grinders is not a proper subject for this book. However, it may be interesting to point out that grinding, to maintain tolerances of plus or minus .0005" is common in everyday production. For very special work, designers have produced modern grinding machines that can achieve an accuracy so exact, that to express it, a new term "micro-inch" (one millionth part of an inch) has been coined. This measurement is now familiar in some industries where special devices for testing have been developed.

To produce this extreme accuracy, grinders are being made heavier to absorb vibration, and more strongly ribbed to give increased rigidity to the machine. Every part that turns or slides receives the most exacting attention so that when these machines are completed at the factory they are the ultimate in accuracy and perfection. The ways and slides of these machines are as flat and as parallel as it is possible to make them. This perfection is of special interest to the scraping operator because it is his problem, in reconditioning the machine, to restore the bearing surfaces to their original accuracy.

Besides the worn flat bearings there are other factors involved in the reconditioning process which if not corrected could aggravate existing defects or even induce new errors. These include worn or defective gearing, feed screws, spindle, spindle bearings etc. The specific treatment required to restore these components to their original accuracy is beyond the scope of this book and therefore will not be treated except in the briefest manner when special circumstances warrant it.

The varieties of grinding machines are so numerous that it would require several volumes to describe separately, the reconditioning processes on each type. They are separable, however, into two general classifications according as to whether they grind cylindrical surfaces, or grind flat surfaces.

To explain the scraping and aligning procedure on the general group of cylindrical grinders, we have selected a Cylindrical Grinder with Universal Workhead as typical of the class. This choice was made because it is a well known, widely used machine. For this demonstration, as in previous ones, an elementary form will again be used.

In order to have the scraping procedure in harmony with conditions as they are found in most shops, we will use the fewest possible number of spotting or testing gages. Reliance will be placed in the few standard tools found in average shops, and when practicable, in the components of the machine employed as Templates.

Sec. 29.1
The Cylindrical Grinder: Components

The cylindrical grinder, illustrated in Fig. 29.1, consists of five members which are the prime concern of the scraping operator. In addition to the fundamental components enumerated below, the grinding machine is often equipped with special attachments which greatly increase the versatility of the machine. The methods of reconditioning these minor parts will not be discussed. When such work is called for, it is thought that the principles and practices recommended for treatment of the various standard parts will, if thoroughly understood, be entirely adequate to cope with this auxiliary equipment.

1. The Bed (1). The main casting of the cylindrical grinder is called the bed. It is a large, heavy casting made of a good grade of cast iron or semi-steel. It is substantially ribbed to provide a rigid foundation for the other

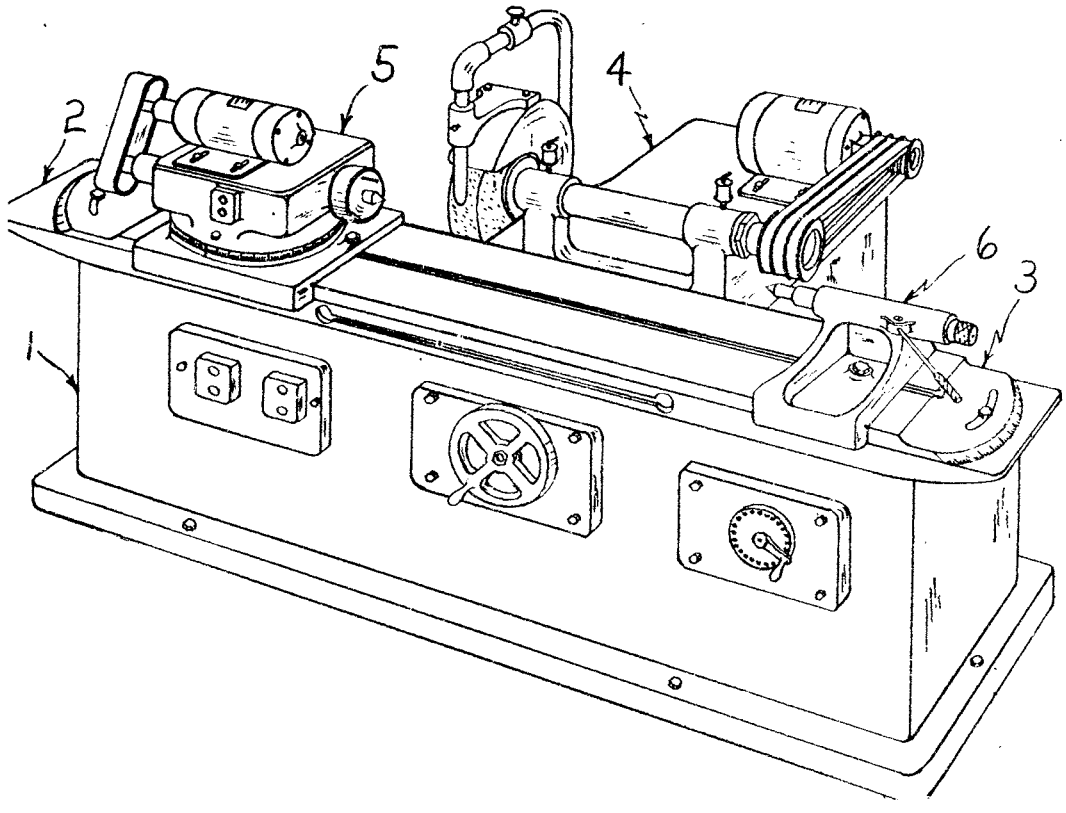

Fig. 29.1 The Cylindrical Grinding Machine.

(1) bed (2) work table (3) swivel plate (4) wheel head (5) work head (6) footstock

components. The bed is constructed with two sets of ways. The longitudinal ways guide the work-table; and the transverse ways support the wheelhead.

2. The Work-Table. (Comprising two parts, the table proper and the swivel plate)
   a) The Table (2) is a long, relatively thin, rectangular casting ribbed for strength. It has two groups of bearing surfaces. Underneath are the slides which bear on the bed ways, permitting longitudinal movement. The top surface of the table supports the swivel plate.
   b) The Swivel Plate (3) rests on the table. It is a long, thin, rectangular casting machined all over. This member has two groups of bearing surfaces. The top bearing surface is distinguished by a T-slot extending longitudinally through the center of the casting. Both the workhead and footstock clamp to the T-slot. A guiding way is incorporated in the top surface and aligns these members. The lower surface has a stud that inserts in a corresponding hole in the table top. The swivel plate pivots around this central stud.
3. The Wheelhead (4). This member is guided by the transverse ways of the bed. It mounts the grinding wheel and an electric motor to drive the wheel.
4. The Workhead or Headstock (5). This member supports one end of a work piece. It mounts an electric motor which drives the work piece by a combination of V-belts, silent chains etc. An integral part of the workhead is a rotating spindle to which a chuck may be attached. The spindle is built to perform two functions:
   (1) To operate as a live center head

where both the work and spindle revolve.

(2) To operate as a dead center head, wherein the work revolves while the spindle remains stationary.

5. The Footstock or Tailstock (6). The function of this member is to support one end of a work piece, usually on a dead center.

Sec. 29.2
The Schedule of Scraping Operations

The various bearing surfaces are separately identified as each member is taken up. However, to acquaint the reader with the general sequence of operations, the groups of bearing surfaces are listed below in the order they will be discussed in the text. The notable thing in this outline is that the table slides are treated twice. First, these surfaces are prepared for use as a template. Later, they are scrape-finished and fitted to the longitudinal ways of the bed.

The wheelhead slides also are given this double treatment. a) Prepared as a template. b) Fitted and aligned to the transverse ways of the bed.

After leveling the bed, the sequence of scraping operations is as follows:

1. Preliminary scraping of the table slides. (Preparation for use as a template on the longitudinal ways of the bed.)
2. The longitudinal ways of the bed.
3. Final fitting of the table slides.
4. The top surface of the table.
5. The top and bottom of the swivel plate.
6. The base of the footstock.
7. The base and swivel of the workhead.
8. Preliminary treatment of the wheelhead slides. (For use as a template for the transverse ways of the bed.)
9. The transverse ways of the bed.
10. The final fitting and alignment of the wheelhead slides.

Sec. 29.3
The Datum Point

Preliminary to actual scraping it is essential to establish a DATUM POINT. Generally speaking, in dealing with the majority of cylindrical grinders, the longitudinal ways of the bed are the most logical and correct selection for a Datum Point. Consequently, all alignments, direct or indirect, are pointed to these bearing surfaces.

As a rule, the longitudinal ways of the bed are quite heavily worn, and reconditioning them calls for special spotting gages. Under the conditions usually found in the average machine shop, special tools are not likely to be available. However, by substituting the table member as the spotting template, as mentioned above, we are able to perform this function nearly as efficiently and just as accurately.

Sec. 29.4
Exploratory Examination

The next step is to dismantle the machine. The workhead, footstock, swivel plate, table, and wheel head are removed from the bed and inspected. Discussion of the various steps in such a survey is given in Sec. 23.3. Reviewing this subject matter before proceeding with the study of the present chapter is therefore advised for the reader. Needed machine repairs which can be performed at this time are assigned to the machine shop. When these details are attended to, the bed of the Cylindrical Grinding Machine is leveled.

Sec. 29.5
Leveling Procedure

It is seen from Fig. 29.2 that the top finished surfaces on the bed are the leveling surfaces and are non bearing. They are shown as (1), (2), (3), and (4) in Fig. 29.3 and Fig. 29.4, representing the transverse and longitudinal ways of the bed, respectively.

The leveling surfaces are first examined for dent burrs. To detect those which escape an ordinary visual inspection, marking medium is applied with either a SURFACE PLATE or a STRAIGHT EDGE. The dent burrs should be removed by filing or scraping, taking care not to lower these areas below the original plane. In other words, just the ridge surrounding the burr is eliminated. When the leveling surfaces are acceptably smooth, the PRECISION LEVEL can be laid on top.

Next the grinder bed is leveled. For

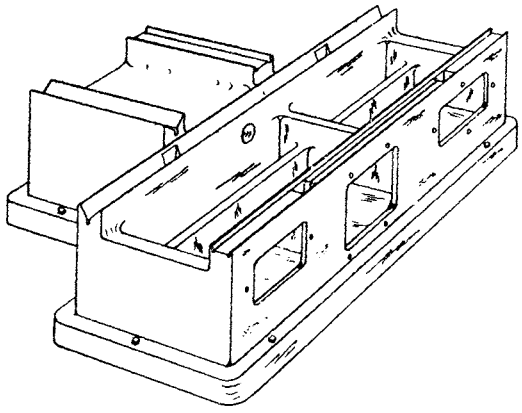

Fig. 29.2 Main casting, or bed, of cylindrical grinder showing the longitudinal and transverse ways. Each set of ways consists of a flat way and a V-way.

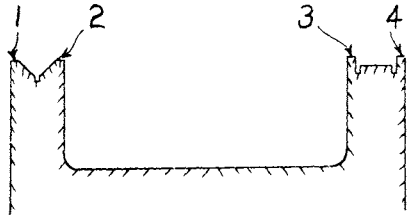

Fig. 29.3 End view of transverse ways of bed showing non-bearing leveling surfaces as (1), (2), (3) and (4).

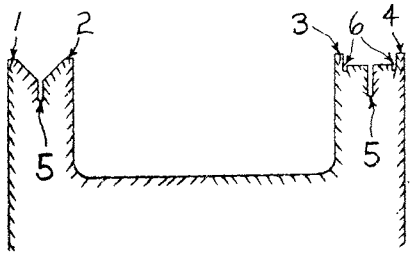

Fig. 29.4 Cross sectional view of longitudinal ways of bed showing non-bearing leveling surfaces as (1), (2), (3), and (4). (5) represents oil channel connecting oil wells. (6) represents grooves provided for scraping clearance and for return of oil to oil well.

a detailed account of this procedure, reference can be made to Sec. 14.10. In brief, the PRECISION LEVEL is placed in several locations on the leveling surfaces to obtain an average over-all reading. First, a check is made crosswise. This will usually necessitate laying a SCRAPED PARALLEL directly on the leveling surfaces thus spanning the distance between the V-way and the flat way of the bed. On top of this bridge is set the PRECISION LEVEL.

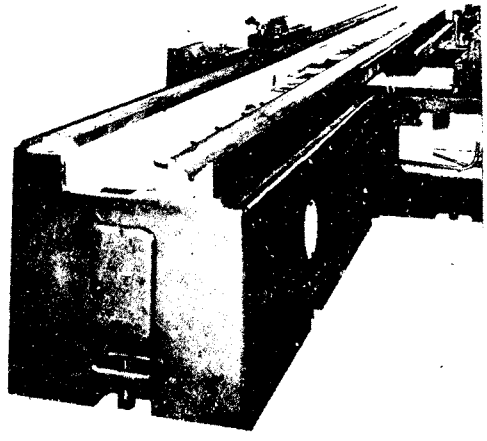

PLATE 58. View of centerless grinder bed with Vee and flat ways finish planed. Observe leveling screws spaced along bed. (Courtesy - Landis Tool Company)

Second, a check is conducted lengthwise. To do this, two small PARALLELS are so positioned as to bridge the leveling surfaces of each bearing and the PRECISION LEVEL is laid on top of them, as shown in Fig. 29.5. The set ups described above are performed successively in two directions, on both the transverse and longitudinal ways of the bed. The checks are repeated one after the other, meanwhile raising or lowering the bed by adjusting the screws, (1), same figure, in the base of the bed casting until the leveling surfaces are as level as it is possible to make them.

After the bed is satisfactorily leveled, the leveling surfaces are re-conditioned. The necessity and importance of this operation is extensively treated in Sec. 14.21.

Following the completion of this task, both longitudinal and transverse ways of

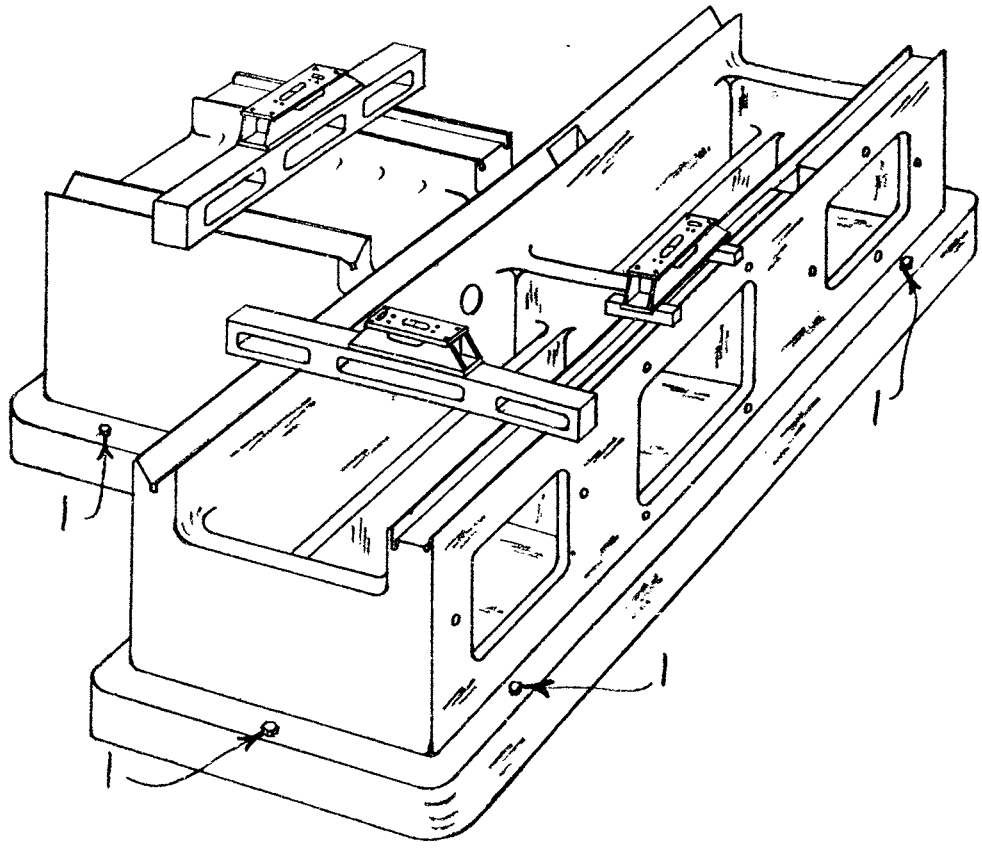

Fig. 29.5 View showing system of leveling the bed from both transverse and longitudinal leveling surfaces.

(1) leveling screws

the bed are thoroughly cleaned of all grit, metal chips, etc. Next a coating of marking compound is applied to the longitudinal ways of the bed. These bed ways, though worn, will now be utilized as a spotting tool while the table slides are prepared as a template.

Sec. 29.6
The Table

The table member, which slides on the longitudinal ways of the bed, has two groups of bearing surfaces. The top surface of the table is shown in Fig. 29.6. A large portion of this surface is recessed (3) thus providing bearing pads (2) to support the swivel plate. The pivot hole (1) is also indicated in the figure. This construction is characteristic of most makes and models of cylindrical grinder tables.

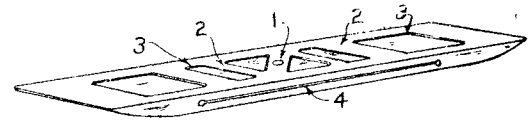

Fig. 29.6 Diagram of top surface of table of cylindrical grinder.

(1) pivot hole (2) bearing pads (3) recessed areas (4) T-slot

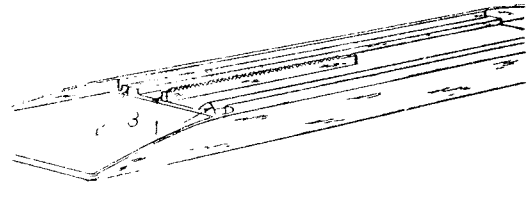

Fig. 29.7 General arrangement of under-side of table showing bearing slides.

(1) inverted V-slide (2) flat slide (3) rack

The under side of the table is illustrated in Fig. 29.7. Principal features are the inverted V-slide (1), the flat slide (2), and the rack (3).

It is the inverted V-slide and flat slide of the table which will be used as a template to spot the V-way and flat way of the bed. Therefore, at this stage, we are primarily concerned with the underneath surfaces or slides of the table. Interest in the top surface of the member is confined to its possible future use as a check point.

Sec. 29.7
First Steps in Preparing the Table as a Template

In lieu of making up a special gage, it is accepted practice to use the table slides for spotting the longitudinal ways of the bed. However, since the slides of the table usually are worn, it is desirable to renovate them sufficiently to serve as an efficient template for the bed. Obviously, the more accurately this is done, the better it will function as a spotting template. While this member, even in its present worn condition, could be utilized as a spotting tool, it is far better to give it a preliminary scraping. Ultimately, the same amount of metal must be removed, regardless of method, but the procedure discussed in the following pages is considered preferable because it makes the table into a more accurate template.

Even with this improvement in the accuracy of the table slides, they still are not to be relied on to indicate surface bearing quality nor register flatness. Their principal purpose will be to help maintain the original angle of the V-way of the bed. In addition, the table slides assist in keeping the V-way and flat way of the bed parallel to their original factory plane. Provision for indicating adequate bearing quality, flatness, and parallelism in the bed ways is secured by a proper utilization of a STRAIGHT EDGE, PRECISION CYLINDER, GAGE BLOCKS, and DIAL INDICATOR.

Before dealing directly with the table slides the following procedure is recommended:

1. Clean the table, top and bottom, of all grit and dirt.
2. Remove the rack (3) Fig. 29.7. This part is secured by bolts or screws and aligned by straight dowel pins. Loosen the bolts and gently tap on the rack near the dowel pins. Usually the rack pulls free with little effort. If considerable pressure seems necessary, investigate to make certain that bolts do not enter it from both sides, which sometimes is the case.
3. A few cycles of scraping is desirable to remove any incidental high spots, burrs etc. which may impair the flatness of the table top. To this end the surface is spotted alternately with a STRAIGHT EDGE and SURFACE PLATE. This procedure will also disclose whether or not a warp is present. If such is the case, the top surface must be worked until it is flat with a surface quality of 3 - 5 bearing spots per square inch. This absolute minimum is required because the table top will be frequently used as a temporary check point, not only for the table slides but also for the ways of the bed.
4. Scrape both slides of the table once all over. This treatment will give the slick and polished slides a fine roughness to which marking compound will readily adhere.

We are now ready to spot the slides of the table. For this operation we will utilize the longitudinal ways of the bed as a quasi-template and alternate with a STRAIGHT EDGE. Speaking generally, the longitudinal ways of the bed will be found quite worn because they receive considerable use. Consequently, in their present condition they are not very efficient as a spotting template. They are useful though as an approximative gage to preserve the inverted V-slide angle on the table and to retain, in so far as possible, the original relationship between the inverted V-slide and flat slide of the table. Furthermore, they may also have some slight value in preserving parallelism between the table slides in the vertical plane. However, to attain flatness and develop surface bearing quality, reliance must be placed in a STRAIGHT EDGE. To test the parallelism between the slides, to the extent thought necessary, a DIAL INDICATOR and an inverted V template will be required.

Let us emphasize again that the purpose in treating the table slides at this time is merely to produce a fairly accurate template with which to spot the longitudinal ways of the bed. The improvement of flatness and parallelism in the table slides is the only reason justifying the expenditure of time and effort to make the table a more efficient spotting template. The table member is not completed at this time. Instead, it is advanced to a semi-finished condition, and then work is suspended, to be resumed after the bed member is perfected. Therefore, the OBJECTIVES that follow may logically be called "preliminary."

Sec. 29.8

PRELIMINARY OBJECTIVES: The Table Slides as a Template. (Inverted V slide and flat slide)

1. To be parallel to the original factory plane.
2. To retain the original angle of the inverted V.
3. To be flat with a surface quality of 5 - 10 bearing spots per square inch.
4. Axes of bearings to be parallel in vertical plane.

PROCEDURE:

The first rule to observe in dealing with the table slides is that they must be treated together. That is, improvement of one bearing must keep in step with the other. To facilitate this program it is a good plan, when spotting the slides of the table, to alternate the tools. The means for transferring the marking medium will consist of the following:

1. The longitudinal ways of the bed.
2. The long STRAIGHT EDGE.
3. A specially prepared inverted V-template.

The longitudinal ways of the bed, though worn, will serve as a rough guide for indicating fulfillment of OBJECTIVES NO. 1 and NO. 2. When the bed is utilized as a quasi-template, marking compound is spread on the longitudinal ways. Then the table is mounted on the ways in a central position. To transfer the marking compound, the table is moved back and forth with a long sweep. This lengthy movement is resorted to because we merely wish, insofar as possible, to keep informed how closely OBJECTIVES NO. 1 and NO. 2 are being carried out. The markings produced on the table slides are examined after the member is removed to a work bench and laid bottom up. In this position the bearings are most accessible.

One precaution should be observed when the grinder table is laid on a work bench for either scraping or spotting purposes. It is important that the weight of the member be uniformly supported along its full length to prevent sag. The table is a relatively thin casting in comparison to its length and therefore bending is apt to be a familiar phenomenon. For additional information refer to the Sec. 3.2. (Bending of Metals)

With the table in a position favorable to accurate observation of the results of the initial spotting cycle, the table slides can be considered individually, though for purposes of scraping and spotting they are treated as a unit. The first thing that will be noted from the markings is that the ends are considerably more worn than the middle section i.e. the slides have degenerated into convex surfaces. (This, incidentally, is the ultimate condition which all sliding members assume and is due to the greater wear at the extremities.) The markings produced by the spotting action of the bed ways are interpreted in accordance with the judgment of the operator, then are scraped in conformity therewith.

Without moving the member from its inverted position, the second cycle of spotting is performed with a STRAIGHT EDGE which should be sufficiently long to overlap the bearings. If the only tool available is too short it can still be used effectively, provided it is manipulated according to the recommendations set forth in Sec. 9.7. In applying the STRAIGHT EDGE to the flat slide, it will be seen that this bearing now occupying an approximately level position will support the entire weight of the tool and therefore can be spotted with little trouble. Reliance, therefore, should be placed in the flat slide as the criterion of flatness, in preference to the sloping inverted V-slide which is more difficult to spot. The position of the latter requires the operator not only to spot the sides of

the inverted V- but also simultaneously to support part of the weight of the STRAIGHT EDGE. However, no serious trouble will be experienced if the precautions described in Sec. 9.8 are observed.

The problem of evaluating the markings must now be considered. During the preliminary scraping cycles, the markings transferred by the bed ways to the table slides may be accepted at face value and so scraped. But during the intermediate and final stages, the markings formed in this fashion are only scrutinized and then wiped off. Their location and appearance should, however, be remembered for future reference. As for the markings produced by the STRAIGHT EDGE, we must depend exclusively on this tool for the indication of surface flatness because, as we have said repeatedly, the bed is unsuited for this purpose due to its worn condition. Both means are used alternately, performing their distinct functions until the job is done.

After each spotting cycle with the STRAIGHT-EDGE, a decision must be made as to which of the high spots on the table slides are to be scraped. In deciding this the notations made of the surface conditions following the last spotting with the bed ways will assist materially. For example, should one edge of the flat slide be scraped harder than the other edge, and should one side of the inverted V-angle be scraped harder than the other side to secure proper fit between the table slides and the bed ways? These and related questions are resolved by an analysis of the markings produced by both tools. We cannot rely with complete confidence on the bed ways to indicate flatness and surface bearing quality, nor can we depend on the STRAIGHT EDGE to disclose parallelism and angular deviation. Neither spotting tool by itself guarantees the attainment of OBJECTIVES NO. 1 and NO. 2. But used together, the markings outlined on the table slides by these means can be evaluated, compared, and correlated with considerably accuracy. After a decision is made in regard to this matter, the scraping operations are directed towards the goals specified.

As the removal of metal proceeds, various tests are performed periodically. In this connection, the important thing to remember is that these tests are essentially preliminary, since they are made, from and to, worn and incompletely scraped surfaces. Consequently, exact readings are not to be too strictly enforced regardless of the type of indicating gage employed. Just what latitude can be permitted in this matter is a question of individual judgment. Much will depend upon the physical condition of the surfaces involved and the experience of the operator.

We may keep a check on OBJECTIVE NO. 1 by using the following set up. Place the table and the wheel head on their respective ways on the bed. After mounting a DIAL INDICATOR on the wheel head, adjust the button to touch the top surface of the table. By moving the table under the DIAL, we can check for parallelism in the vertical plane between the table top and slides in the longitudinal direction, as shown in Fig. 29.8.

To test in the transverse direction, we employ the out and in movement of the wheelhead. Ordinarily, the slides of the wheelhead and the transverse ways of the bed show relatively fewer signs of wear. This combination will, therefore, be very close to the original factory-new plane and will provide an acceptable check point even without any preliminary treatment. To take advantage of this normal condition, the following set up is suggested:

Set the contact button of the DIAL INDICATOR on the table top. Move the wheelhead so that the instrument passes across the width of the table, as represented in Fig. 29.8.

The critical reader might question the reliability of any set up employing the transverse ways of the bed and the wheelhead slides. Such a procedure is allowable, however, despite the fact that these surfaces have not been scraped, because precision accuracy at this time is not essential. We are seeking merely a close approximation. If the table slides remain reasonably parallel to the table top, measured in both directions, OBJECTIVE NO. 1 is being secured. For example, a deviation of a few thousandths from a zero-zero reading in the distance measured is permissible. We wish to attain OBJECTIVE NO. 1 closely, yet not spend too much time on this phase of the job.

Another equally suitable method of checking this condition proposes the use of a PRECISION LEVEL placed

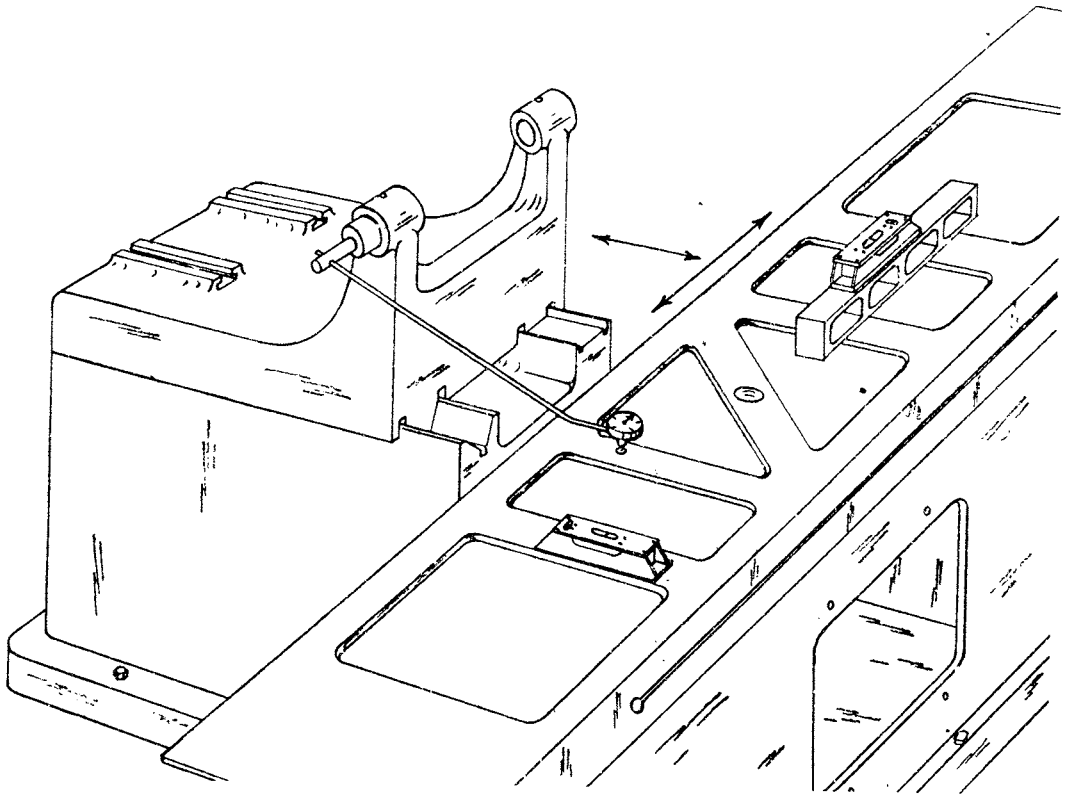

Fig. 29.8 Checking parallelism of table slides to top of table in vertical plane using DIAL INDICATOR or PRECISION LEVEL.

successively lengthwise and cross-wise on the table top. If the bubble centers, or nearly so, OBJECTIVE NO. 1 is achieved.

In connection with OBJECTIVE NO. 2, the original angle of the table inverted V-slide may be preserved more easily if a short inverted V-way spotting template is made up, as suggested in Sec. 12.15. There are two methods of designing such a template. In the first place, the operator could duplicate the original angle, which information can be obtained from the manufacturer. Secondly, the angle of the template could also be generated by spotting it on the least worn portion of the inverted V-slide of the table prior to any scraping therefrom. Regardless of how it is made, the template will prove helpful because it maintains the desired angle and permits both sides of the inverted V-slide of table to be worked in together.

Progress towards OBJECTIVE NO. 2 is judged by observing the markings transferred by this gage. A uniform over-all coloration on each side of the V-slide indicates that the original angle of the bearing is being preserved.

The spotting should be alternated between the prepared template and a STRAIGHT EDGE. Occasional sweeps of the table along the ways of the bed should also be included in the spotting routine. By scraping "straightdown" OBJECTIVES NO. 1 and NO. 2 can be closely approximated.

The bearing quality required by OBJECTIVE NO. 3 should be secured at this time.

While attaining the first three "preliminary" OBJECTIVES for the table slides, we must not lose sight of the necessity of keeping the bearing slides parallel in the

vertical plane. This must be done to justify the time and effort now being expended to make the slides an efficient spotting template for the bed ways. The test for parallelism specified by OBJECTIVE NO. 4 is conducted periodically as follows:

Mount a DIAL INDICATOR on the inverted V-template as shown in Fig. 29.9.

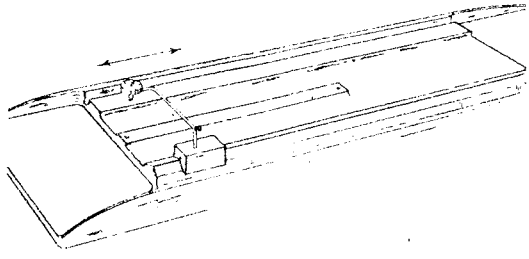

Fig. 29.9 Testing parallelism of inverted V-slide to flat slide in vertical plane.

Adjust the button to the flat slide and take readings along its full length. Scraping is continued on one or both slides, as required, until a zero-zero reading is obtained, thus satisfying OBJECTIVE NO. 4.

We might interject at this point that, the ultimate scrape-finished alignment of the table slides in the vertical plane permits a tolerance of .0002" per 12". How closely to match this precision at this time must necessarily be left to the discretion of the operator.

Inability to attain an approximate zero-zero reading may be due to other causes than ineffective scraping. For example, it may be attributed to faulty test apparatus. In the preceding check, illustrated in Fig. 29.9, the Surface Gage is assumed to be sufficiently stable to produce fairly accurate readings without counter-balancing. If the span between the inverted V-slide and flat slide is too wide, the device should be counter-weighted to compensate for the overhang of the rod and DIAL.

It must be remembered that with this set up a two point contact is used i.e. the two sides of the inverted V-slide of the table provide the support for the template. A three point contact is necessary to assure true stability but this is impossible to achieve on account of the constructional features of the inverted V-slide of the table. As a result of this tendency towards instability, great care must be exercised in manipulating the apparatus to avoid false readings.

A deviation in the reading of the DIAL INDICATOR does not necessarily mean that the axis of one slide is tilted up or down in relation to the axis of the other slide, although this may be so. When the reading varies, another possibility is that the inverted V-slide is not straight. A "wind" may have been scraped into it as a result of improper or careless spotting. Consequently, as the template is moved along the V-slide, it tilts either towards or away from the flat slide, depending upon the direction of the "wind," and the reading is affected. This induces the erroneous impression that the two slides are not correctly aligned in the vertical plane, whereas the real fault is a twist in the inverted V-slide. Unfortunately, with the limited apparatus being described, a "wind" cannot be detected by a DIAL INDICATOR. This defect, as we have stated before, is caused by improper application of the STRAIGHT EDGE and is detectable by correct use of this tool. (Refer to Sec. 9.8 and also read Sec. 22.7.)

All four "preliminary" OBJECTIVES having been attained, the table is now ready to be used as a template to spot the ways of the bed member. As we have emphasized all along, the scraping performed thus far is merely preliminary, and the table slides are by no means completed.

This incompleteness is due mainly to the difficulty in accomplishing OBJECTIVE NO. 4 with exactness utilizing the test procedure described above. It would, of course, be entirely practicable, if a more exact template were desired at this stage, to apply other and more precise testing methods, such as the application of the Water Level System, shown in Fig. 22.8.

Although the present condition of the slides falls short of the ultimate perfection achieved when they are scrape-finished and aligned parallel in the vertical plane, nevertheless, they now are in far better condition than before the work started. The value of the table, as a template for the longitudinal ways of the bed is, therefore, considerably enhanced.

Sec. 29.9

OBJECTIVES: The Longitudinal Ways of the Bed.

1. To be parallel to the original factory plane.
2. V-way to be straight.
3. Original V-way angle to be preserved.
4. The V-way and flat way to be parallel in the vertical plane.
5. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

To obtain maximum precision when spotting the longitudinal ways of the bed, alternate between the table slides used as a template and a STRAIGHT EDGE. Preferably, the latter tool should be sufficiently long to cover the length of the bed ways, yet narrow enough to insert between the leveling surfaces elevated above the adjacent flat way. (See Fig. 29.2) Sometimes, these two considerations cannot be reconciled. In such a case, the longest STRAIGHT EDGE which will fit must be used. To simplify the present procedure, we will assume that there is available a STRAIGHT EDGE of adequate length, yet narrow enough to fit between the leveling surfaces.

After each spotting by either tool, the bed ways are scraped. Greater reliance in determining flatness is, of course, placed in the STRAIGHT EDGE because of its known accuracy. The slides of the table, on the other hand, are still an uncertain quality. Any variation in the coloring, or distribution of the high spots on the bed ways, revealed by consecutive applications of the two spotting gages, will be judged in relation to the known accuracy of the STRAIGHT EDGE as compared to the as yet doubtful accuracy of the table slides. There is a possibility the latter may be inaccurate, because it is extremely difficult to measure precisely the parallelism in the vertical plane between an inverted V-slide and flat slide without using a much more complicated testing technique than the one recently discussed in Sec. 29.8. The reason may be attributed to the dissimilar forms of the bearing surfaces.

To check for OBJECTIVE NO. 1 tests are undertaken first in the transverse direction, then in the longitudinal direction.

TEST TRANSVERSE DIRECTION:

The flat way is tested separately by setting a PRECISION LEVEL cross-wise on it. (Interposing gage blocks between the instrument and the flat way will be necessary to clear the leveling surfaces.) The bubble in the glass should center.

Since the V-way cannot be tested in the same direct manner, the following set up must be performed alternately. Place the table on the bed, and lay a PRECISION LEVEL cross-wise on the table top. It can be fairly assumed that both bed ways are approximately parallel to their original factory plane if the bubbie in the vial is centered.

An alternative test that is quite efficient can be executed as follows: A DIAL INDICATOR is fastened to the wheelhead with the button in contact with the table top. The wheelhead is then traversed inward, as shown in Fig. 29.8. The reading will disclose which bearing, the V-guide or the flat way, must be scraped lower to achieve OBJECTIVE NO. 1. In either of the procedures just discussed, a tolerance of a few thousandths in the transverse direction is permissible because the top surface of the table has not as yet been scrape-finished. Consequently, it may be slightly tapered in the transverse direction with respect to its slides, or be otherwise defective. These conditions are rectified later. Our immediate purpose in applying this test is to achieve OBJECTIVE NO. 1 as closely as possible. This accomplishment will insure that the pressure imposed on both bearing surfaces by the table will be equalized, thereby extending their service life.

If this test is satisfied, we may be reasonably certain that the longitudinal bed ways are now closely aligned to their original plane, measured in the transverse direction. The basis for this confidence is three fold:

First, is the entirely reasonable assumption that the slides of the wheelhead and the transverse ways of the bed are reliable as a check point. These bearing surfaces seldom are heavily worn because no shop can afford very long to turn out inferior grinding on a seriously deteriorated machine. Under normal use it is the longitudinal bed ways and table slides of a cylindrical grinder which

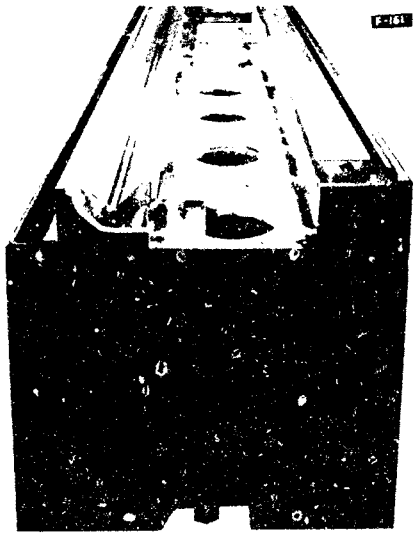

PLATE 59. Close-up of Vee way and flat way of bed of centerless grinder after hand scraping. (Courtesy - Landis Tool Company)

require repair sooner than the transverse bed ways or wheelhead slides. Consequently, the line of travel of the wheelhead should be very close to what it was when the machine was brand new.

Second, in the process of converting the table into a template, the table slides were so scraped as to retain their original relationship to the table top in the transverse direction.

Third, we can safely assume that the table top is in fair condition because it has already been tested for warp and corrected if necessary.

TEST LONGITUDINAL DIRECTION:

Continuing the procedure, we prepare to check the bed ways in the longitudinal direction. This is accomplished with the following set up; after removing the table, place a PRECISION CYLINDER in the V-way of the bed at one end. Incidentally, the diameter of the cylinder should be of a size permitting contact to be made approximately half way into the V. Next a LEVEL is laid on the CYLINDER, and the position of the bubble is noted. Observations are made at several places along the bed. If the bubble is centered in all cases then the V-way of the bed is parallel with the original factory plane i.e. level measured longitudinally, as specified in OBJECTIVE NO. 1. The error allowed is shown in Fig. 29.10. The flat way is tested in like manner.

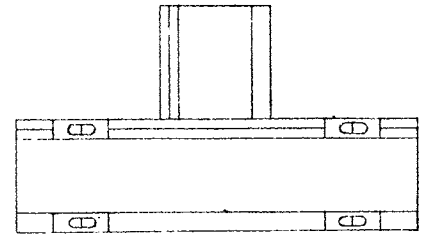

Fig. 29.10 Bed ways - level in longitudinal direction. Max. tolerance - 0.00025" per foot.

It might be well to emphasize that the bed casting was previously leveled, employing the non-bearing leveling surfaces to accomplish the job. This present operation, though also involving the use of a LEVEL, is entirely separate and distinct, and has for its purpose the determination of the alignment of the ways to the original plane in the longitudinal direction. (The original plane having been level.)

Straightness of the V-guide, as specified in OBJECTIVE NO. 2, requires accurate checking. One method of judging straightness is by means of careful spoting with a long STRAIGHT EDGE. A lack of uniformity in the coloration, or uneven distribution of the markings denotes a "wind." For beds of short to medium length this system is quite satisfactory, but for long beds the operator must set up a taut wire and microscope. This subject was discussed in Sec. 22.8. A tolerance of .00025" per 12", uniformly distributed over the entire length of the ways is allowed.

Checks for OBJECTIVE NO. 3 are made periodically as the scraping work is carried on. Each time the table is removed after a spotting cycle, the appearance of the bed ways is carefully appraised. An even dispersion of the marking medium on the flat way and both sides of the V-guide is desired. Obviously, to effect this condition removal of metal must be delicately performed on both bearings. A slightly deeper cut is directed against the surface that shows evidence of receiving heavier pressure. OBJECTIVE NO. 3 is deemed accomplished when a final spotting with the table reveals

that the markings are uniformly distributed and similar in coloration on the flat way and matched equally on both sides of the V-way.

As a preliminary test for OBJECTIVE NO. 4 during initial scraping operations, a ground PRECISION CYLINDER of suitable size is placed in the V-guide. It is judged appropriate if it makes contact about half way in the V. Next a DIAL INDICATOR, mounted on a Surface Gage, is set on the flat way as illustrated in Fig. 29.11. The button of the instrument is adjusted against the CYLINDER so that as the Surface Gage is moved cross-wise on the flat way, between the leveling surfaces, the DIAL reading will rise to maximum and then recede. (It is necessary for the pointer to fail back to make certain that a maximum has been reached.) The maximum reading is the one selected as a basis for judging parallelism in the vertical plane. This procedure is repeated at several points along the ways meantime comparing the results.

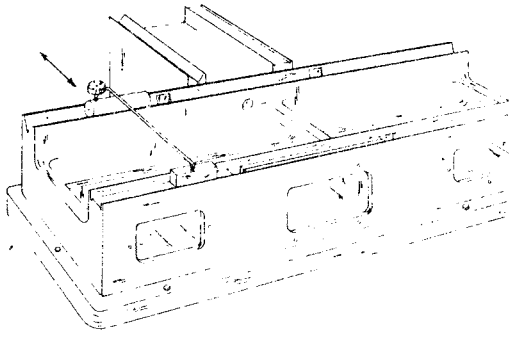

Fig. 29.11 General arrangement of apparatus for testing parallelism of V-guide to flat way of bed in vertical plane.

When additional cycles of testing and scraping produce no noticeable improvement in the surface, the limits of accuracy for this type of test have been reached.

It is of the highest importance that the bed ways meet the specifications of OBJECTIVE NO. 4. A smooth, uniform feed of the work-table is essential and this can be accomplished only on perfectly straight and parallel bed ways. If these characteristics are lacking, metallic contact results which is indicated by a jerky movement of the table. If operated in this condition, such erratic behaviour would destroy, or at least impair, an otherwise acceptable finish on the work piece being ground. The lubricant alone cannot prevent metal to metal contact because the oil film is of only microscopic thickness and easily ruptured.

To be absolutely certain that the bed ways are parallel in the vertical plane, a more precise test must be adopted. A PRECISION CYLINDER of suitable diameter and length is placed in the V-guide at one end of the bed. GAGE BLOCKS are built up, one by one, on the flat way until a PRECISION LEVEL resting on a SCRAPED PARALLEL positioned as shown in Fig. 29.12, indicates level. Then the set up is transferred intact to the other end of the bed. If the bubble also centers at that end, the bed ways are parallel in the vertical plane. The tolerance shown in Fig. 29.13 is acceptable if uniformly apportioned along the entire length of the bed.

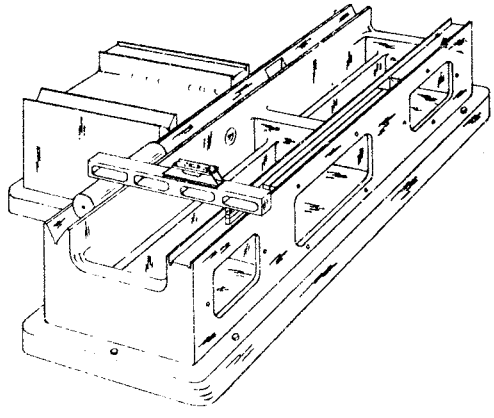

Fig. 29.12 Method of testing ways of bed for parallelism in the vertical plane using PRECISION LEVEL and GAGE BLOCKS.

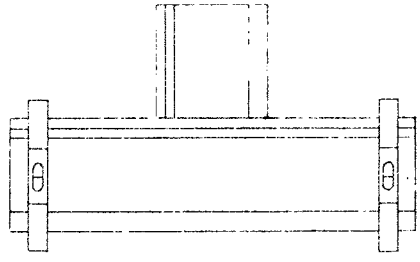

Fig. 29.13 Longitudinal ways of bed parallel in vertical plane. (No twist permitted) Max. tolerance (±) 0.00025" per foot.

Another method, called the Water Level System, is especially useful where the bed is of considerable length and when the accuracy demanded justifies the expense of the necessary auxiliary equipment. This procedure is described in some detail in Sec. 22.12.

All OBJECTIVES must be attained simultaneously.

Thus to recapitulate: The longitudinal ways of the bed are judged completed provided they can be spotted uniformly by a STRAIGHT EDGE laid anywhere on them. Reliance is placed in the STRAIGHT EDGE to indicate flatness and surface bearing quality; and on the various precision indicating tools, to register parallelism. A uniform bearing quality and parallel ways regulate the density of the oil film on which accurate work size and acceptable finish depend.

If all the OBJECTIVES have been conscientiously executed, the longitudinal ways of the bed are now finished and are as near perfect as they can be made. We will presently use these bearing surfaces as a spotting template for the table slides.

Continuing the sequence, the final scraping of the table slides is discussed next. As the reader will recall, we have dealt extensively with these bearing surfaces when preparing this member as a template. (Refer to Sec. 29.8) Since there is now available a finished, perfected template, the longitudinal ways of the bed, the following operations will, therefore, be much simplified.

Sec. 29.10

FINAL OBJECTIVES: The Slides of the Table

1. To be fitted to the longitudinal ways of the bed with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

Preparation for the spotting is begun by cleaning the table slides. Next the bed ways are coated with a thin film of marking compound. (If desired, the slides may be coated instead.) Then the table member is placed centrally in position on the bed ways.

Now that everything is in readiness to spot the table slides, we should discuss briefly some of the problems peculiar to treating table members of grinder machines.

In the first place, in fitting the table slides to the bed ways, the operator should not overlook the fact that ultimately the table top must be aligned dead level, that is, parallel to the bed ways. Therefore, the operator should, from time to time, test the table top for levelness. Thus, if any misalignment of the table top is evident, part or even all of the error may be rectified while fitting the table slides to the bed ways. The operator should always view each surface with relation to the whole machine and never adopt such a narrow point of view that one bearing surface is scrape-finished to the exclusion of all considerations relative to other surfaces. This is just another application of the axiom "scrape straight down."

Secondly, even though the ways of most grinder beds are as long, or longer, than the table slides, the latter member should not be pushed back and forth a distance greater than is necessary to transfer the marking medium. That is to say, the table should not be traversed so far it overhangs the bed ways. This is simply standard spotting procedure.

Thirdly, although complete reliance can now be placed in the bed as an accurate spotting template, we continue to apply a STRAIGHT EDGE alternately while spotting the table slides. It would not be necessary except for the special problem created by the cored slots in the flat way of the bed. This topic is so important it will be discussed separately in a later paragraph.

Another point to emphasize is that the table is subject to bending. Furthermore, due to size and weight factors, no manipulation of the table can be attempted beyond placing it on the bed and pushing and pulling it to transfer the compound.

If careful spotting is coupled with judicious scraping, we are, in time, able to observe a uniform coloration over the entire length of the slides. This in itself is not conclusive proof that the table slides are flat, even though the bed ways constitute a perfect spotting template.

This contradictory situation arises if the table is under stress, that is to say, bending slightly due to a convex surface being scraped into the slides. Even a

slight convexity allows the table to rock slightly, thereby causing the entire bearing surface of the slides to be spotted uniformly, creating the illusion of flatness.

Sec. 29.11
Checking a Table for a Convex Surface

As the table slides near completion, convexity becomes a matter of increasing concern. An infallible test for this condition consists of deliberately scraping the center half of the table slides a little more deeply than is justified by the indicated markings. By this strategem we observe, following the next spotting cycle, one of two possible results, viz:

1. The overall coloration of the marking on the table slides, including the central portion, remains relatively unchanged.

(or)

2. The markings at the center half of the table slides are fainter, indicating less pressure; and the coloration at the ends of the slides is denser, revealing a heavier pressure.

In the first case, where no appreciable change in coloration occurs, the evidence points to a high middle area, i.e. convex area. It is then obvious that the uniform coloring previously observed was due to the rocking of the table and was not an indication of true flatness. To remedy this situation, the middle part of the table slide is scraped heavier than the ends until there is unmistakable evidence that the latter are slightly higher. The ends are then gradually lowered until a uniform coloration is seen on the table slides. These bearings are now flat by every practicable standard.

In the second case, where as the result of our little experiment, the ends disclose signs of more pressure, we deduce that earlier the table slides were truly flat and not convex after all. Knowing now for sure that the middle portion is not convex, the ends can be scraped by gradual stages restoring the overall original condition. A uniform coloration over the entire bearing surface is the criterion of flatness and parallelism in the slides but, as we have warned, it must not be improperly generated by a convexity in the table slides.

Sec. 29.12
Reducing Sag in a Table

The process of spotting and scraping a work table is peculiar in that a low middle area i.e. concavity is seldom generated except by the operator's own deliberate efforts. Consequently, on all types of table slides, it is far more likely that any concavity observed in the longitudinal direction is the effect of sagging. This phenomena eventuates if the casting is improperly blocked while treating the table slides, particularly if the position is maintained for a prolonged period.

By improper blocking is meant placing the table on a bench for scraping or spotting purposes and neglecting to support one or more portions of the casting. This causes the unsupported segment to sag.

When a sag develops in a grinder table, scraping is the only certain method of correcting this fault. However, it is possible to reduce the amount of work involved by taking advantage of the tendency of the table to bend and settle. (Refer to Sec. 3.2) In a few words, it is standard practice to leave the table on the bed ways for several days, for example over the week end. The work can usually be so scheduled. This interval allows the table to unbend and straighten before the finish scraping is performed. After this discussion of matters pertinent to the table slides, we will return to the subject of fitting the table slides to the bed ways.

A uniform coloring of the markings on the table slides is a reliable guide that the weight of the member is evenly distributed over both the V-way and flat way of the bed. It is just as essential that the slides of the table be flat and parallel in the vertical plane, as it was for the bed ways to be. The effect of non-parallel ways (and slides) on accuracy and finish in the work piece was discussed previously in Chapter 24.

OBJECTIVE NO. 1 specified in Sec. 29.10 is not satisfied unless the markings are of one consistent coloration. This is the criterion by which we judge that the table slides are correctly fitted to the bed ways. Scraping continues until this condition prevails.

(The critical reader doubtless has noticed that we have made no mention of straightness in discussing the table slides. This was not an oversight because table

slides properly fitted to the bed ways are presumed straight.)

Sec. 29.13
Checking the Grinder Table for Clearance

The work table of most grinding machines is so constructed as to furnish maximum protection to the bearing ways of the bed from dust and coolant. This is accomplished by designing the table casting so that it encloses the bed bearing ways. This inclosure does not involve physical contact, although the separation of the table from the bed casting is deliberately made as small as practicable. On account of this, it is essential to make certain during scraping operations, that no part of the two members touches at any point throughout the maximum travel of the work table except, of course, on the bearing surfaces themselves.

Frequently, a considerable quantity of metal must be removed from the bearing surface of both the table and bed to align them properly and provide good bearing quality. Consequently, there is a distinct possibility that the original aperture between the two members may be so narrowed by the scraping process that a metallic contact will ensue. If this happens, the offending portions of either the bed or the table casting must be filed or ground away to permit the necessary clearance.

A good method of verifying the clearance between the bed and table castings, is to position a light at one end of the grinder bed and sight towards it from the other end. The table is moved to different positions while the operator sights along both ways in succession. If the light can be seen clearly at all points, clearance between the bed and the table is adequate.

Sec. 29.14
Cored Slots or Oil Channels

Narrow slots, connecting oil wells, are found in the longitudinal ways of the bed of some types of grinding machines. They are illustrated in the elementary machine shown in Fig. 29.2. This channel provides a means of keeping the oil in adjoining wells at the same level for uniform lubrication of the ways. The cored slot accomplishes this purpose admirably, but in so doing it creates an unusual problem for the scraping operator.

The cored slots are an integral part of both longitudinal ways of the bed. However, the cored slot in the V-way can be disregarded because it is sunk below the sliding bearing surface of the inverted V-slide of the table member and, therefore, makes no contact with it. (See Fig. 29.4) The cored slot in the bed flat way is quite another matter and a brief study of the design will disclose why this is so. It is clearly evident that the slot eliminates all wear on that portion of the table flat slide located immediately above it. The effect of this reduction of wear on a localized area is to produce, over a period of time, a narrow ridge of metal on the flat slide. Eventually a surface condition develops which is illustrated in exaggerated form in Fig. 29.14.

In correcting this strip of surface a STRAIGHT EDGE is suitable for spotting purposes. As for the scraping process, it is not enough merely to keep this strip flat and level with the adjacent area, we must lower it. Unless provision is made for this feature the flat slide wears unevenly during normal operation. After a period of time, a narrow ridge of relatively unworn bearing surface is formed. The danger in this is that in the ordinary course of operating the machine, the ridge will emerge from the slot onto the bearing surface of the bed flat way. It will lift the table causing metal to metal contact, or otherwise affect the travel of the work-table to the detriment of the work piece being ground.

If the machine is devoted to grinding short lengths of work over an extended period of time, the high-area condition can become very pronounced. When a production changeover requires a longer

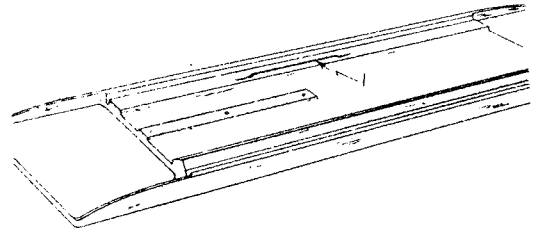

Fig. 29.14 View of work table before scraping showing ridge of metal formed on flat slide by cored oil slot.
(1) ridge

movement of the table, the ridge emerges from the cored slot and rides the bed flat way. This ruptures the oil film, causes an uneven movement of the work-table, and affects the accuracy of the grind.

To avert this development we proceed as follows: The maximum travel of the work table, both to the left and right of center is determined. Then that narrow portion of the table flat slide which will be directly over the cored slot during the maximum table travel, must be cut out i.e. lowered below the plane of the adjacent surface. By removing metal to a depth of about one thousandth of an inch, trouble in the immediate future is obviated.

Sec. 29.15
Oil Wells

Oil wells being a practical proven system for lubricating the sliding bearings will frequently be encountered on grinding machines. In view of the difficulty with the cored slots discussed above, a critical reader might question the effect of the oil wells on the bearing surfaces of the table member. Undoubtedly they do have some effect on the wearing performance of the table slides. However, since the wells span the full width of the bearing surface, no remedial treatment is possible.

Sec. 29.16
Spring Mounted Rollers

Sliding members are often lubricated by means of spring mounted rollers, located in oil wells, spaced at intervals along the ways. The rollers dip into the oil and spread it on the slides as they pass back and forth over the rollers. Two types of oiling roller are shown in Fig. 29.15.

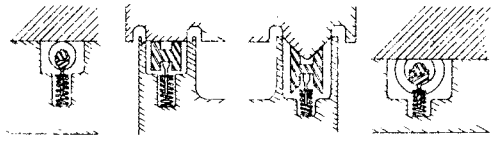

Fig. 29.15 End and side sectional views of oiling rollers inserted in oil wells and making contact with the table slides.

Sec. 29.17
Notes on Lubrication

When ways are lubricated by applying oil directly to the surfaces, no special problem is involved.

In some machines the ways are lubricated by oil by-passed from the hydraulic system. This means that the requirements of the hydraulic system usually determine the kind and viscosity of the oil. In consequence, the surface bearing quality of slides and ways must be adapted to the kind of oil in the hydraulic system, instead of vice versa.

Slides and ways are also pressure lubricated. The continuous outward flow of oil away from the ends of the table slides, effectively prevents the entrance of foreign matter. As a further protection the bed ways are completely enclosed in telescoping guards attached to the table. These features require no special treatment.

Sec. 29.18
Preparation for Touching Up the Ways of the Bed and Slides of the Table

Before turning our attention to the top part of the table, the bearing surfaces of the bed and table are prepared for a final touching up, although the actual operation is performed later. (See Sec. 29.48)

Touching up removes any isolated high spots remaining on the ways and slides and is a recommended practice. It is not a mere expedient to make up for inadequate workmanship but a pefecting process. It is called for because some high spots undoubtedly were not clearly exposed - failed to show clearly - during the spotting of the bed and table. The reason for this is that, during the final fitting, the table was moved only slightly and infrequently when transferring the marking compound, and all high spots did not register prominently.

Preparation consists of applying a thin film of marking compound to the longitudinal ways of the bed. Then the table is placed in position upon them. Now during the scraping and alignment testing of other members, such as the wheelhead, footstock, etc. the table will be moved back and forth on the bed ways a number of times, for various distances. High spots which failed

to appear during the regular spotting of the table slides and bed ways will now, as a result of this repetitious movement, be plainly disclosed as highlv polished spots. These high spots will be picked off later i.e. pinpointed.

Sec. 29.19
OBJECTIVES: The Top Surface of the Table

1. Table top to be parallel with table slides in longitudinal direction.
2. Table top to test level in transverse direction.
3. Table top to have a surface quality of 5 - 10 bearing spots per square inch.

PROCEDURE:

The spotting process on the top surface should be alternated between a SURFACE PLATE and a STRAIGHT EDGE. However, before undertaking this operation it is advisable to check the degree of error in the alignment.

To test for parallelism, as required by OBJECTIVE NO. 1, attach a DIAL INDICATOR to the wheelhead. Place the button in contact with the table top as shown in Fig. 29.8. Push the table under the instrument meantime noting the reading. It is bad practice to move the table its maximum length under the DIAL as this causes the ends to over hang the bed excessively. Since this possibility could lead to inaccurate readings, it is advisable to limit the travel to the center half of the table top. Only enough movement need be allowed to be certain that any deviation from parallelism with the table slides is not in excess of the tolerance represented in Fig. 29.16.

The test for OBJECTIVE NO. 2 in the transverse direction is conducted by laying a PRECISION LEVEL cross-wise on the table top and then noting the position of the bubble. To minimize error, this check can be repeated at several locations. The plus or minus tolerance is shown in Fig. 29.17.

When the size of the job is ascertained, actual work can begin. The top surface of the table is spotted and scraped-in most efficiently if the member is placed in position on the bed ways. Cradled in the rigid bed casting there is no possibility

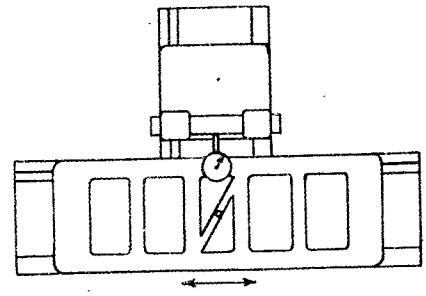

Fig. 29.16 Table top parallel with slides in longitudinal direction. Max. tolerance 0 to .00025" per foot.

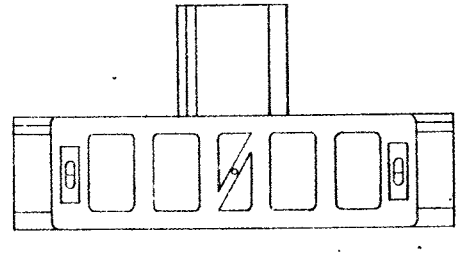

Fig. 29.17 Checking levelness of table top. Max. tolerance (±) 0.00024" per foot transverse direction.

of a warp developing. This is preferable to removing the table to a bench where it would be necessary to block it correctly to prevent sag.

The tests above mentioned are repeated at intervals as the scraping proceeds. It is advisable also to apply the quick X Test from time to time to detect the incipient formation of a "wind" on the long table surface. The usual precautions should be exercised in scraping around the perimeter of the pivot hole and recessed areas.

As usual all OBJECTIVES are completed together.

This finishes the table and we turn now to the Swivel Plate.

Sec. 29.20
The Swivel Plate

This is the casting which rests on the table and supports and aligns both the workhead and the footstock. Top and bottom views of the swivel plate are shown in Fig. 29.18a and Fig. 29.18b respectively.

As these views show, the swivel plate is a relatively thin member in comparison to its width and length. It features three surfaces that require scraping, namely, bottom and top surfaces and the guiding way. Centrally positioned in the bottom of the swivel plate is a stud. With the stud inserted into the pivot hole in the table top, the swivel plate can pivot about this axis for taper grinding.

Sec. 29.21
The T-slot in the Top Surface of the Swivel Plate.

In the elementary design described in these pages, the T-slot extending the full length of the top surface is a means for holding down the workhead and footstock. It has no alignment function whatever and consequently is never scraped. Fig. 29.18a shows that the slot is milled at an angle to the top surface, not square with it. This arrangement helps pull the workhead and footstock tightly against the guiding way. Thus, in this design, it is the guiding way which aligns the members horizontally with respect to each other, not the T-slot.

Some constructions utilize T-slots in which the throat is milled square with the swivel plate top. In such cases the slot is adaptable not only for hold-down purposes but also for aligning dependent members. This requires a corresponding change in the design of the bases of the workhead and footstock. Tongues, fitted to the workhead and footstock, are then inserted into the T-slot thereby aligning these members with respect to each other in the horizontal plane.

Not infrequently a dovetail way or an inclined V and flat way will be utilized for aligning the footstock and workhead.

The next step in the sequence is to scrape both the top and bottom surfaces of the Swivel Plate. Since the problem involved in scraping them is similar for each, it will be unnecessary for purposes of explanation to treat them separately. This consolidation also makes for brevity.

Sec. 29.22
OBJECTIVES: Bottom and Top Surfaces of the Swivel Plate.

1. Bottom surface to be flat.

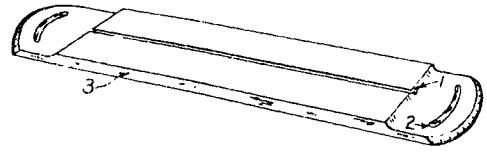

Fig. 29.18(a) View showing upper surface of Swivel Plate.

(1) angled T-slot (2) clamping slot (3) guiding way

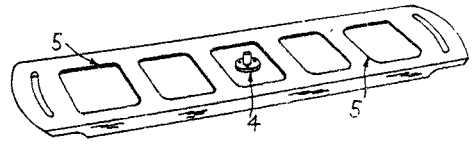

Fig. 29.18(b) View of bottom surface of Swivel Plate.

(4) stud (5) recessed areas.

2. Top surface to be parallel to bottom surface.
3. Both surfaces to have a surface quality of 5 - 15 bearing spots per square inch.

PROCEDURE:

Little wear will have occurred on the bottom surface of this member as it is not a sliding bearing, according to our definition of the term. Consequently, after the swiveling stud (4) Fig. 29.18b is removed, this surface can be dealt with quite easily. It is spotted with a STRAIGHT EDGE and a SURFACE PLATE applied alternately.

The swivel plate may be placed on the work bench while the bottom surface is scraped, but if this is done precautions must be taken to block it properly. This is essential in order to prevent the member from warping.

Due to the liklihood of warping it may be preferable to support the casting on the scrape-finished top surface of the table while spotting and scraping. The advantage of this position is that it will obviate the necessity of blocking to prevent sag. However, it will be necessary to spread a layer of kraft wrapping paper between the two members to minimize the sliding action caused by the pressure of a scraping stroke, as well as to protect the finish of the top surface of the table.

A uniform coloration of the markings

on the surface indicates flatness. Utilization of the "X" test to detect "wind" will afford additional proof that OBJECTIVES NO. 1 and NO. 3 are attained.

After the bottom surface is satisfactorily completed, the swivel plate is inverted. In this new position the same vigilance must be exercised to prevent the casting from sagging as this condition prevents the accomplishment of OBJECTIVE NO. 2.

Periodic checks should be made for parallelism. A micrometer may be used for this purpose, with measurements being taken along the sides and also at the four corners. Scraping is continued on the upper surface until the "mike" readings are within the tolerance shown in Fig. 29.19.

An alternative plan for treating the top surface favored by some operators is as follows: After the bottom surface is finished as described above, the swivel plate is placed in position on the table which had been scraped previously in the regular sequence, and is known to be flat. The swivel plate is clamped to the table top and tested as shown in Fig. 29.8. If errors are noted, it will not be removed but will be spotted and scraped while clamped.

To maintain a check on parallelism lengthwise between the upper and lower surfaces, a DIAL INDICATOR is mounted on the wheelhead. The button is set in contact with the swivel plate. Then the table carrying the swivel plate is traversed under the button. To test the top of the swivel plate in the transverse direction, a PRECISION LEVEL is laid crosswise. The tolerances allowed for both directions is represented in Fig. 29.19.

The required surface bearing quality demanded by OBJECTIVE NO. 3 is scraped-in simultaneously.

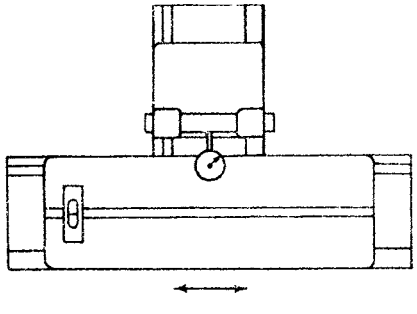

Fig. 29.19 Checking parallelism in vertical plane between bottom and top surfaces of Swivel Plate. Max. Tolerance 0.00025" per foot.

Sec. 29.23

OBJECTIVE: The Guiding Way of the Swivel Plate

1. To be parallel to the original factory plane
2. To be straight and have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

Treatment of the guiding way requires scraping "straight down." Spotting is accomplished with a STRAIGHT EDGE of appropriate length. Both operations can be performed while the swivel plate is clamped to the table. Every effort must be taken to make this surface truly flat because this characteristic will determine the accuracy of the horizontal alignment of the workhead and footstock.

Under ordinary conditions when scraping this surface, any deviation from parallelism with the T-slot in the horizontal plane would be slight and hence can be ignored. Furthermore, the normal amount of play between the clamping bolt and clamping hole in the workhead and footstock would be sufficient to prevent binding and hence possible misalignment of the members. Consequently, no alignment test with the T-slot would be necessitated.

Both OBJECTIVES are attained together.

Sec. 29.24

Alignment of Swivel Plate to Table

All surfaces of the swivel plate have now been scrape-finished. The next operation is the assembly and alignment of the swivel plate on the table. After fastening the pivot stud (4) to the casting, this member is placed in position on the table top.

The swivel plate is now adjusted so that the guiding way is parallel to the table movement. To accomplish this, the swivel plate is lightly clamped to the table. A DIAL INDICATOR is attached at some convenient point on the front side of the bed casting with the button positioned on the guiding way of the swivel plate. The table is traversed by hand thus moving the guiding way under the DIAL button. Meanwhile the swivel plate is tapped until the

guiding way is aligned to the table movement, within the tolerance indicated in Fig. 29.20. When this result is achieved, the swivel plate is clamped securely in that position. Attention to this important detail assures that the workhead and footstock, the next two members to be worked upon, will be properly aligned to each other and to the table movement.

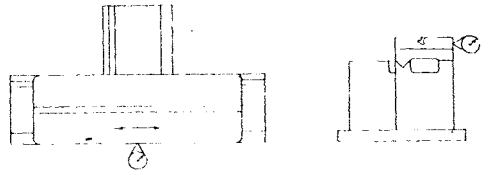

Fig. 29.20 Permissible tolerance for alignment of guiding way of swivel plate with table movement. Max. tolerance 0.00012" per foot.

Sec. 29.25
The Footstock

The footstock shown in Fig. 29.21 is adjustable longitudinally along the guiding way of the swivel plate and may be clamped at any position. The function of the footstock is to support one end of the work piece, while the other end is held and rotated by the workhead spindle. In the elementary design offered for study, two surfaces are scraped, namely:

1) The flat slide, or base.
2) The guided slide.

The footstock member is selected for scraping at this time, in preference to the workhead, because under normal operating conditions, it is moved more frequently along the swivel plate top and hence will show somewhat greater wear. The significance of this is that the axis of the footstock and the workhead spindles must be aligned to each other in the vertical plane i.e. with reference to height above the top of the swivel plate (although there are other considerations also). Consequently, it is logical to finish the more abraded member first, thereby establishing a minimum level for the axes of the spindles. This procedure makes it possible for the axis of the other member to be lowered to match it. This is good scraping practice and should be standard procedure in all similar cases, unless altered by special circumstances. See note below.

NOTE: From a practical standpoint it is often advisable to postpone finish scraping the footstock bearing surfaces until the workhead is also just short of completion. When this stage is reached, further alignment tests are given both members, individually and jointly. After the approximate misalignment attributable to each is known, the scraper can alternate between the two members, gradually reducing the error on each, so as to complete them simultaneously.

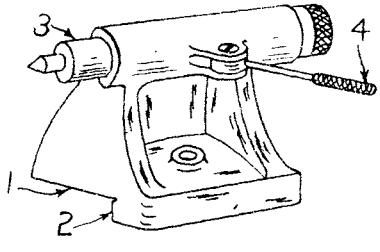

Fig. 29.21 Diagram of Footstock (top view).
(1) flat slide, or base (2) guided slide
(3) spindle or ram (4) retard handle

Sec. 29.26
Testing the Ram for Fit

Before any scraping is attempted on the bearing surfaces of this footstock member, it is essential for the various working parts to be in good condition. Among the factors which will affect the accuracy of the member and hence of the machine is the fit of the footstock ram or spindle to its housing. The footstock ram must be a nice sliding fit in the housing. Any apparent side play will have a detrimental effect, not only on the accuracy of the work being ground but also on the quality of the finish. The footstock is one of the chief offenders when chatter impairs the finish of the work. One simple method of determining whether chatter is caused by looseness of the ram in its housing is to apply the Shake Test. (Sec. 22.5) To take a reading a sensitive DIAL

INDICATOR must be used. A movement not exceeding .0001" is permissible.

Sec. 29.27
Testing the Alignment of the Ram Hole of the Footstock.

Another very important requirement concerns whether the axis of the tapered hole of the ram is concentric with the axis of the ram. To verify this alignment, a test bar is prepared having a tapered shank ground to fit the tapered hole in the ram. The bar should have a straight portion of about 12". The application of the test is as follows:

The ram is withdrawn from its housing in the footstock. Then the test bar is inserted in the tapered hole of the ram. Next the connected parts are mounted between centers on say a lathe, and tested as described in Sec. 15.13. If no error is apparent, the axis of the tapered hole is concentric with the axis of the ram. On the other hand, should the tolerance be exceeded it will be necessary to rework the tapered hole of the ram to provide the essential accuracy.

Inasmuch as the average footstock ram does not extend any considerable distance outside its housing, difficulty would be experienced in utilizing the ram to align the footstock. Therefore, since the aforementioned test disclosed that the axes of the ram hole and ram are concentric, we may utilize the test bar inserted in the ram hole as a true extension of the ram to align the footstock.

Sec. 29.28
OBJECTIVES: The Base or Flat Slide of the Footstock.

1. Axis of ram to be parallel to table movement in the vertical plane.
2. To be fitted to the top of swivel plate with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

To spot the footstock base represented in Fig. 29.22, marking compound is spread on the top surface of the Swivel Plate. Transfer of the medium is effected by sliding the base of the footstock back and forth a short distance. While the members are positioned on each other is a convenient time to inspect the groove for clearance. Alternate applications of a SURFACE PLATE can be made also, to facilitate the spotting process.

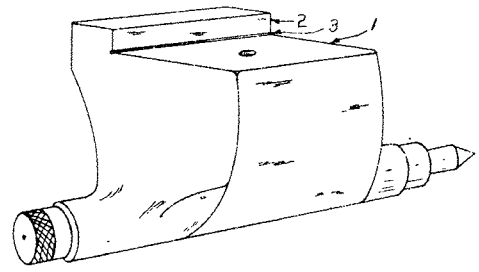

Fig. 29.22 Bottom view of footstock.
(1) flat slide (2) guided slide (3) groove

Scraping is interrupted periodically to test for OBJECTIVE NO. 1. For this purpose the test bar is inserted in the tapered hole of the footstock ram. Then a DIAL INDICATOR is mounted on the wheelhead with the button adjusted to touch the test bar at the vertical diameter, as shown in Fig. 29.23a. The table is traversed thus sliding the test bar under the DIAL button. Notice should be taken of the readings at points (a) and (b) on the bar. Scraping is terminated on the footstock base only when the alignment is accurate and within the tolerance allowed in Fig. 29.23b.

The bearing quality must be adequate, as specified.

Sec. 29.29
OBJECTIVES: The Guided Slide of the Footstock

1. Axis of ram to be parallel to table movement in horizontal plane.
2. To be fitted to the guiding way of swivel plate with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

Marking medium is applied to the guiding way (3) of the swivel plate, which will be used as a spotting template for the surface in question. After placing the two members in contact, the groove should be examined for clearance. The guided slide of the footstock is then scraped. Checks

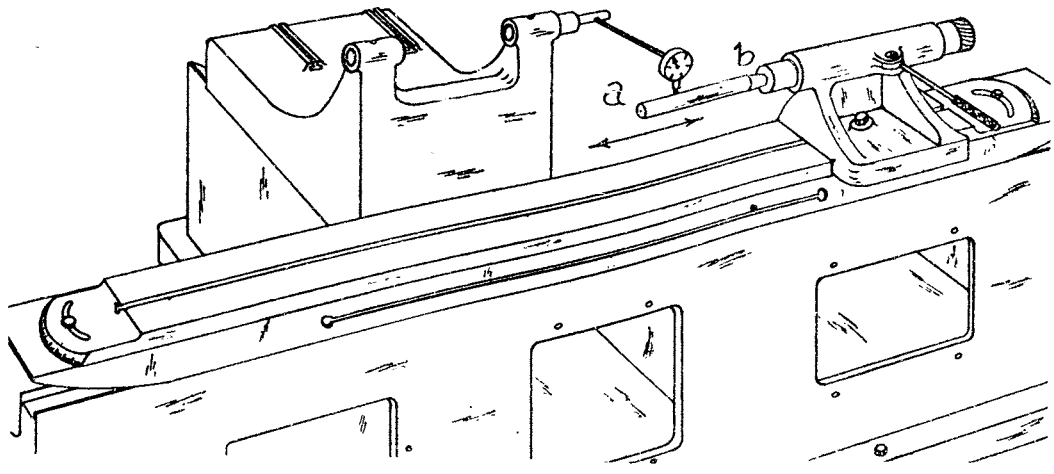

Fig. 29.23(a) Testing alignment of footstock in vertical plane. Readings are taken at (a) and (b) on the test bar.

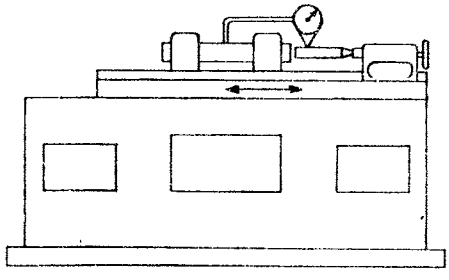

Fig. 29.23(b) Axis of ram parallel with table movement in vertical plane. Max. tolerance 0.0004" per foot. (Free end rising only).

should be made periodically for OBJECTIVE NO. 1.

This testing procedure is similar to the preceding test except that the INDICATOR button is now positioned at the horizontal diameter of the test bar. The table is moved as before and readings are obtained at (a) and (b) as represented in Fig. 29.24a. The unilateral tolerance shown in Fig. 29.24b cannot be exceeded.

Both OBJECTIVES should be completed together.

NOTE: It is a good practice to spot and scrape the two bearing surfaces of

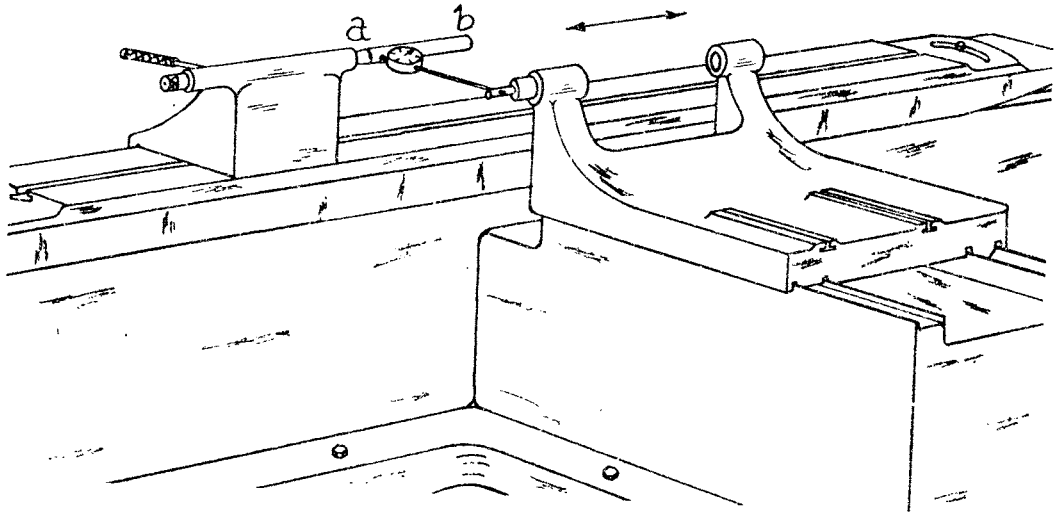

Fig. 29.24(a) Checking alignment of footstock in horizontal plane. Readings are taken on test bar at (a) and (b).

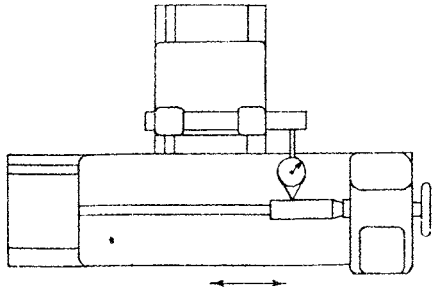

Fig. 29.24(b) Axis of ram parallel with table movement in horizontal plane. Max. tolerance 0.0004" per foot. (Free end inclined towards grinding wheel)

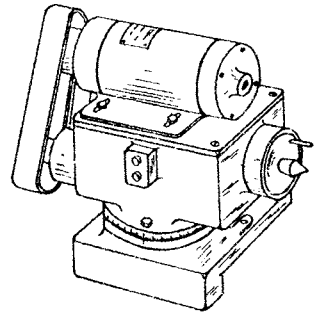

Fig. 29.25 View of work head of cylindrical grinder.

the footstock separately but to conduct the alignment tests on both concurrently, as a time saving measure.

Sec. 29.30
The Workhead

This member is adjustable along the swivel plate and may be clamped at any position. The function of the workhead is to support one end of the work piece while rotating it.

An important part of the workhead is the spindle. The workhead spindle is hollow and contains the live center. The spindle nose I. D. is ground taper and the nose O. D. is threaded to take adapters, face plates, or chucks. With a work piece held in the chuck, the workhead can be swiveled for grinding steep tapers. Though interesting, these matters are not pertinent to our subject. We are concerned, in this discussion, only with the correct alignment of the member and not with the many and varied constructional features found in workheads generally.

Fig. 29.25 illustrates a typical workhead composed of two parts. The upper part, or head, swivels on the lower part, or base, up to 90^0 each side of center, and clamps at any point. It has only one surface that needs scraping namely the swivel slide (1), shown in Fig. 29.26.

The lower section, or base, clamps directly to the swivel plate. The three bearing surfaces of the base are shown in Fig. 29.27.

Preliminary to any scraping on the several surfaces of this member, there must be assurance that the spindle is in

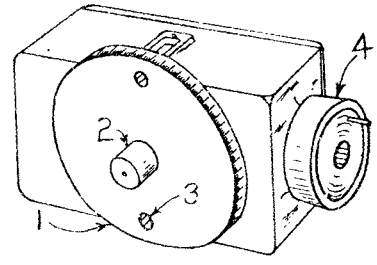

Fig. 29.26 Diagram of upper part or head of workhead showing principal features.

(1) swivel slide (2) aligning pivot stud
(3) clamping T-bolt holes (4) spindle nose

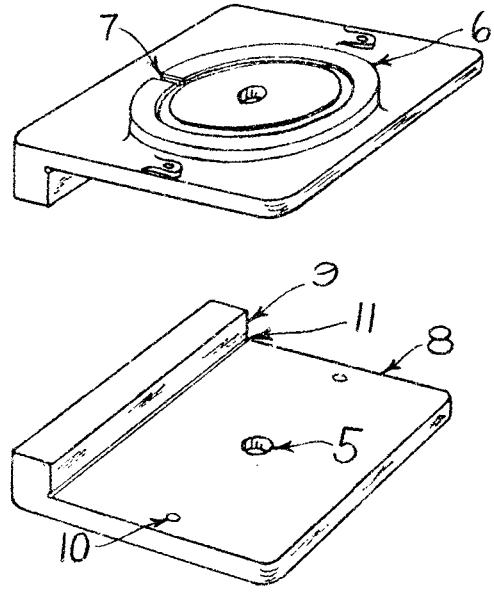

Fig. 29.27 View of lower part or base of work head

(5) aligning pivot hole (6) swivel way (7) circular T-slot (8) flat slide (9) guided slide (10) workhead clamp bolt holes (11) groove

good mechanical shape. Ordinarily, repairs affecting the spindle are not made by the scraper even when their need is indicated. Such work is usually assigned to the machine department. Nonetheless, since the scraping operator must align the member, and do so accurately, it is advisable for him to conduct two tests on the spindle to eliminate it as a possible factor of error. While these tests are being conducted the workhead is clamped on the swivel plate.

Sec. 29.31
Workhead Spindle Center Run Out.

PROCEDURE:

The set up shown in Fig. 29.28 is practically self-explanatory and therefore we shall not bother with more description. It tests the live center for run out. The tolerance indicated must not be exceeded.

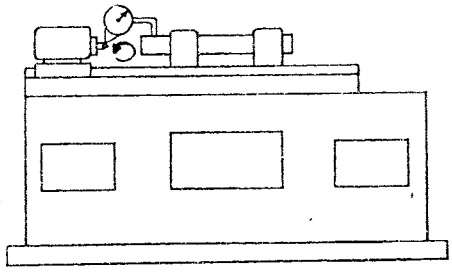

Fig. 29.28 Workhead spindle center run out. Max. Tolerance 0.0002".

Sec. 29.32
Spindle Run Out.

PROCEDURE:

A test bar ground to fit the taper in the spindle is required equipment for this test. The target length of the bar should be about 12" and have a suitable diameter. Possibly the test bar used previously in testing the footstock can be employed again, provided tapers in both spindles are identical. In this connection it is advisable again to warn "Never bush test bars."

The test bar is inserted into the tapered hole in the spindle. A DIAL INDICATOR mounted on a Surface Gage is positioned on the swivel plate, and its button is adjusted to touch the test bar. As the test bar is revolved, readings are taken near the spindle nose, then at the free end. These readings are compared.

The tolerance allowed is shown in Fig. 29.29. If it is not exceeded, the axis of the tapered hole in the spindle is correctly aligned with the axis of the spindle. In this case, scraping operations on the bearing surfaces of the workhead can now commence. On the other hand, if the tolerance is exceeded the spindle must be repaired.

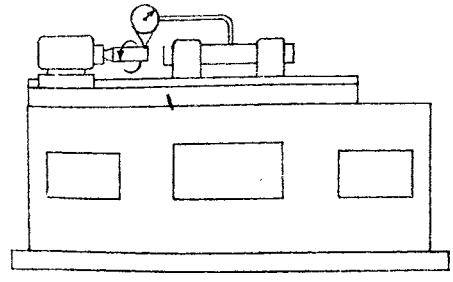

Fig. 29.29 Workhead spindle run out. Max. tolerance at nose 0.0002"; at 12" 0.0004".

Sec. 29.33
OBJECTIVES: The Swivel Slide of the Workhead

1. To be parallel to the axis of the spindle in the vertical plane.
2. To be parallel to the original factory plane.
3. To have a surface quality of 10–15 bearing spots per square inch.

PROCEDURE:

Before undertaking to deal with the swivel slide, the amount of error should be determined. This surface can be tested for OBJECTIVE NO. 1 by mounting the workhead on PARALLELS set on a SURFACE PLATE, as shown in Fig. 29.30. After inserting a test bar in the spindle, a run out test is conducted to find the mean position of eccentricity error. Then the bar is turned so as to place the mean position in the vertical plane. Next a Surface Gage with attached DIAL INDICATOR is laid on the SURFACE PLATE and a test is made from end to end of the bar along the vertical diameter, as shown. A zero-zero reading is required. This test

is repeated periodically during scraping operations.

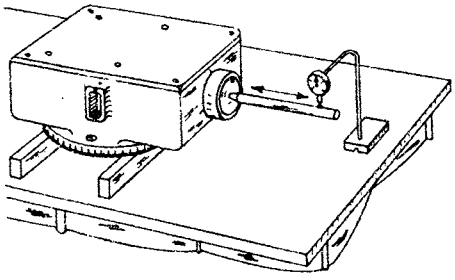

Fig. 29.30 General arrangement of apparatus for testing parallelism of swivel slide to axis of spindle in vertical plane.

The misalignment being known, we may proceed to spot the surface for which a SURFACE PLATE will be an appropriate tool.

To satisfy OBJECTIVE NO. 2 the operator should endeavor to scrape "straight down" to avoid tilting the workhead sidewise. A minimum of scraping will usually suffice since little wear occurs on this surface.

Sec. 29.34
The Workhead Base

This unit is composed of three surfaces which are scraped in the order set forth below.

The swivel way (6)
The flat slide (8)
The guided slide (9)

Fig. 29.27 shows the surfaces mentioned.

Sec. 29.35
OBJECTIVES: The Swivel Way of the Workhead Base

1. To be parallel to the original factory plane.
2. To have a surface quality of 10 — 15 bearing spots per square inch.

PROCEDURE:

The swivel way (6) is spotted most easily on a SURFACE PLATE. Scraping is done at a work bench.

Since this surface normally receives very little wear it therefore needs only a light treatment. Of course, if it is warped more work is required. In any case, by scraping "straight down" OBJECTIVE NO.1 can be fulfilled. The requisite surface quality is produced simultaneously.

The head should now be assembled on the base of the workhead. The zero calibration is aligned with the marker, and the two units are clamped together. Next the workhead is mounted on the top surface of the swivel plate and there fastened.

Sec. 29.36
OBJECTIVES: The Flat Slide of the Workhead Base

1. Axis of workhead spindle to be parallel to table movement in vertical plane.
2. Axis of spindle in 90^0 position to be parallel to swivel plate top in the vertical plane.
3. Axes of spindles (test bar between centers) to be parallel with table movement in vertical plane.
4. To be fitted to top surface of swivel plate with a surface quality of 10 — 15 bearing spots per square inch.

PROCEDURE:

In treating this surface, inspection of the groove (11) for adequate clearance should be the first assignment. Spotting operations on the flat slide (8) are elementary. The spotting is alternated between a SURFACE PLATE and the top surface of the swivel plate member.

The alignment tests, which are somewhat difficult to execute, are performed consecutively at intervals following the scraping cycle.

Proximity to OBJECTIVE NO. 1 is determined with the following set up: A tapered shank test bar is inserted into the spindle, and a run out test is made to assure correct seating. When the mean position is found, the test bar is turned to place it in the vertical plane. A DIAL INDICATOR is now mounted on the wheelhead with the button adjusted to touch the test bar at the vertical diameter, as shown in Fig. 29.31a. The table is traversed so that the test bar can be indicated at points (A) and (B). The unilateral tolerance

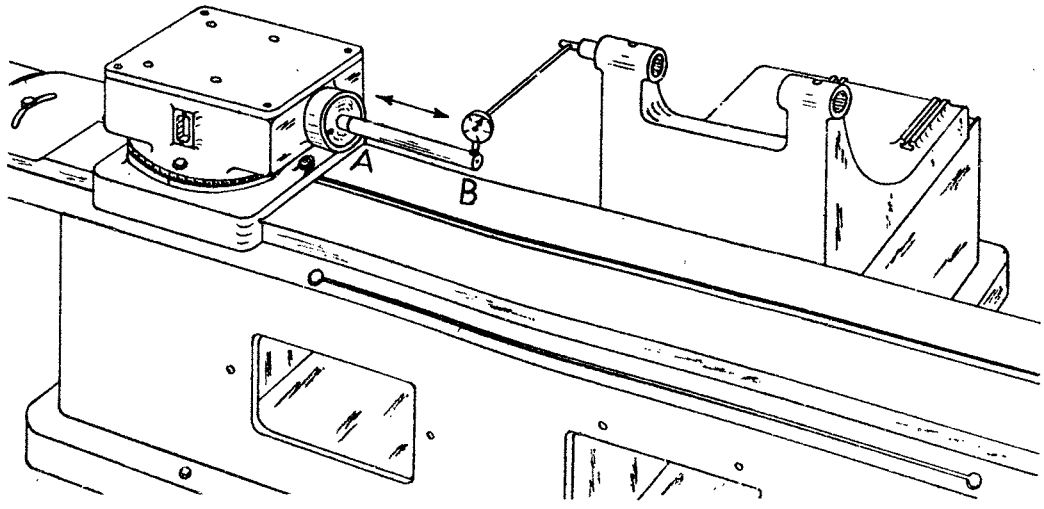

Fig. 29.31(a) Showing method of checking vertical alignment of workhead spindle axis to table movement.

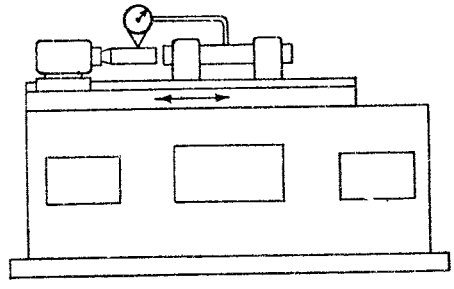

Fig. 29.31(b) Axis of workhead spindle parallel to table movement in vertical plane. Max. tolerance 0 to 0.0008" per foot. (Rising towards free end of test bar).

represented in Fig. 29.31b cannot be exceeded.

To test for OBJECTIVE NO. 2, the spindle of the workhead is swiveled to the 90° position. The head is then re-clamped to the base. After finding the mean position of eccentricity error on the test bar by a run out test, it should be turned to the vertical plane. A Surface Gage with attached DIAL INDICATOR is now placed on the swivel plate. Measurements are conducted from the top surface of the swivel plate to the vertical diameter of the test bar at points (A) and (B). The tolerance allowed in this direction is the same as shown in Fig. 29.31b. Incidentally, both this test and the preceding one can be executed with equal facility if the workhead is mounted on PARALLELS set on a SURFACE PLATE. Fig. 29.32 shows this alternative procedure testing for OBJECTIVE NO. 2.

OBJECTIVE NO. 3 is tested by another set up for which we will need a straight, cylindrical test bar with center holes at each end. The bar will be supported between the workhead and footstock centers

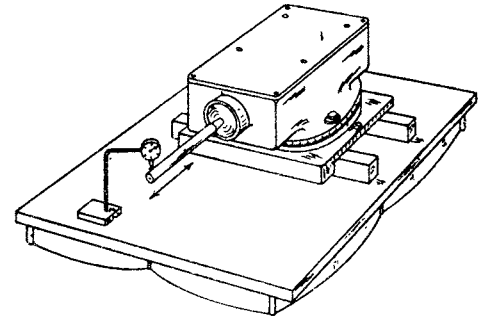

Fig. 29.32 Testing parallelism of flat slide of workhead to axis of spindle in vertical plane with head swiveled to 90° position.

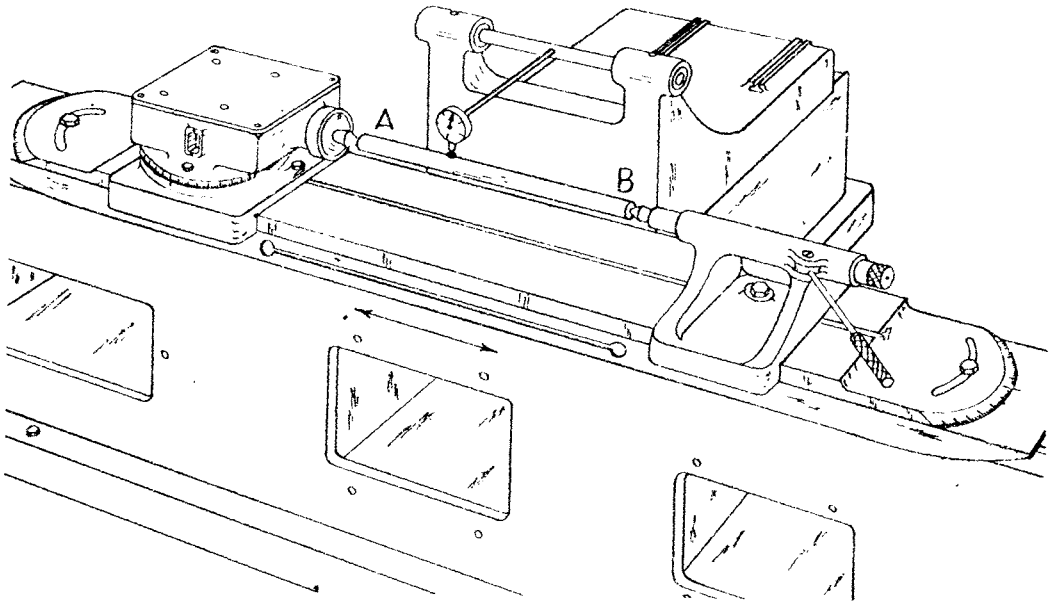

Fig. 29.33(a) General arrangement of parts for checking vertical alignment of workhead and footstock axes to table movement.

as illustrated in Fig. 29.33a. By mounting a DIAL INDICATOR on the wheelhead, the DIAL button can be adjusted to touch the test bar at the vertical diameter. The table is moved longitudinally, so that the test bar will slide from (A) to (B) under the DIAL button. The unilateral tolerance indicated in Fig. 29.33b cannot be exceeded if correct alignment is to be achieved.

By fitting the flat slide of the workhead to the top surface of the swivel plate with the requisite surface quality, the specifications of OBJECTIVE NO. 4 are met.

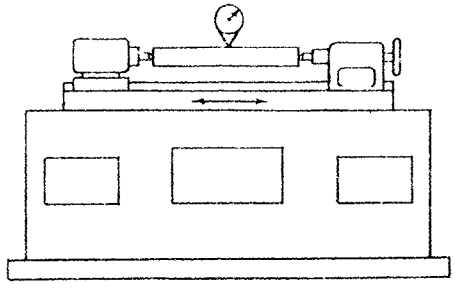

Fig. 29.33(b) Axes of centers parallel with table movement in vertical plane. Max. tolerance 0 to 0.0004". (High at footstock end.)

It might be well to point out that a perfect alignment in the vertical plane is virtually impossible unless the next surface to be discussed, the guided slide of the headstock base, is simultaneously scraped and aligned in the horizontal plane. Experienced mechanics will, therefore, work both surfaces jointly.

Sec. 29.37

OBJECTIVES: The Guided Slide of the Workhead Base

1. Axis of workhead spindle to be parallel to table movement in horizontal plane.
2. Axis of spindles (test bar between centers) to be parallel to table movement in horizontal plane.
3. To be fitted to guiding way of swivel plate with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

A common source of difficulty in the spotting operation is inadequate clearance in the groove. This, of course, has already been pointed out but neglect of

this detail can cause so much trouble that we bring it up once more.

The guided slide should be spotted with a STRAIGHT EDGE. Using the guiding way of the Swivel Plate as a template will also help to develop the proper fit.

The set up to determine OBJECTIVE NO. 1 requires a DIAL INDICATOR to be mounted on the wheelhead. Other apparatus includes the previously used tapered shank test bar which is inserted in the spindle. The mean position of eccentricity error of the bar is found by a run out test and turned to the horizontal plane. Then the DIAL button is adjusted to touch the test bar at the horizontal diameter. By moving the work-table, readings are taken on the bar at points (A) and (B).

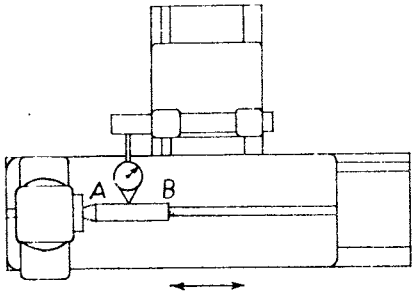

Fig. 29.34 Axis of workhead parallel with table movement in horizontal plane. Max. tolerance 0 to 0.0004" per foot. (Free end of test bar inclined towards grinding wheel.)

Fig. 29.34 indicates the tolerances. If this amount is exceeded, accuracy is attainable by either of two methods, viz:

a) Unclamp the head from the base, swivel as required and reclamp.
b) On units which do not have the swiveling feature, the guided slide of the workhead base must be scraped to provide the necessary alignment.

OBJECTIVE NO. 2 is checked by mounting a DIAL INDICATOR on the wheelhead. A cylindrical test bar is then placed between centers. The DIAL button is adjusted to touch the test bar at the horizontal diameter. The work table is traversed thereby moving the test bar against the DIAL button from point (A) to (B), as indicated in Fig. 29.35. If the reading on the instrument is less at (A) than at (B) then additional scraping is needed on the guided slide of the workhead to achieve OBJECTIVE NO. 2.

On the other hand, if the guided slide of the workhead base has been overscraped, then the DIAL reading will be greater at (A) than at (B), and correction of the error must be accomplished by re-scraping the guided slide of the footstock.

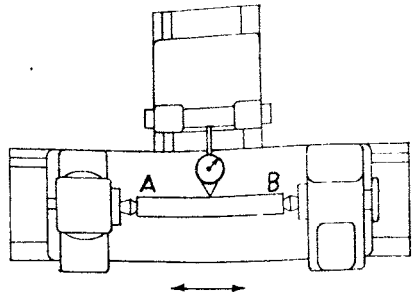

Fig. 29.35 Axes of centers parallel with table movement in horizontal plane.

Alignment of the guided slide of the workhead in the horizontal plane is facilitated if the alignment of the flat slide in the vertical plane is achieved simultaneously. Good practice favors co-ordinating the treatment of both surfaces.

In addition to achieving the necessary alignments, the guided slide of workhead base must be fitted to the guiding way of the swivel plate, as specified in OBJECTIVE NO. 3.

Sec. 29.38
The Transverse Ways of the Bed

Having completed the workhead, we turn to the transverse ways of the bed. The transverse ways consist of one V-way and one flat way as shown in Fig. 29.36. The function of these bearing surfaces is to align and support the wheelhead member.

Spotting of the transverse ways can be started as soon as a template is prepared. The wheelhead will be utilized as the template.

Sec. 29.39
Preparing the Wheelhead as a Spotting Template.

How much time and effort will be

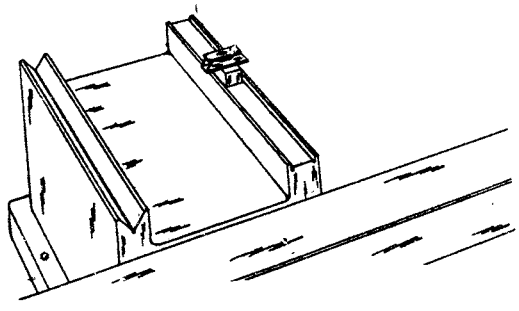

Fig. 29.36 Testing levelness of flat way of transverse ways of bed in crosswise direction by means of a PRECISION LEVEL laid on a PARALLEL.

needed to prepare the slides of the wheelhead as an efficient spotting template will, of course, depend upon their physical condition. Inasmuch as the wheelhead does not move rapidly when in operation, an inspection of the bearing surface will doubtless reveal fewer signs of wear than on equivalent surfaces i.e. the slides of the table. Extensive preliminary scraping of the wheelhead slides should, therefore, be unnecessary. It is a good plan, however, to spot the inverted V-slide and flat slide with a STRAIGHT EDGE, and if burrs are found to scrape them away. In any case, it is advisable to cut below the slick and polished surfaces imparting to the slides a fine roughness to which marking compound will readily adhere.

All of this scraping should be executed "straight down," and must be performed with regard for the alignment of the V-slide and flat slide. Since the problem involved in perfecting these alignments is similar to that discussed previously in preparing the slides of the table as a template it will save repetition to refer the reader back to the methods given in Sec. 29.7 and Sec. 29.8.

The principal points to watch are keeping the wheelhead slides parallel in the vertical plane and preserving the original angle of the inverted V-slide.

Now having at hand an adequate spotting template, we continue the sequence.

Sec. 29.40

OBJECTIVES: The Transverse Ways of the Bed.

1. Original V-way angle to be preserved.
2. Ways to be parallel in the vertical plane.
3. In-feed movement of wheelhead to be parallel to axis of spindle of workhead (in the 90° position) in the vertical plane.
4. In-feed movement of wheelhead to be square with table movement.
5. To have a surface quality of 10 -15 bearing spots per square inch.

PROCEDURE:

Since the bed casting was previously leveled, treatment of the transverse ways can begin directly. The spotting operation on the ways is performed with two different tools applied alternately. First, the wheelhead bearing surfaces serve as a ready-made template to help maintain OBJECTIVE NO. 1. Second, a STRAIGHT EDGE is used to indicate flatness.

After each application of the wheelhead as a template, a visual check is made to determine if the colored markings on the transverse bed ways are uniform. Although retaining the original V-way angle is essential, the operator should not lose sight of the fact that each side of the V-way must support its share of the weight of the wheelhead. Similarly, it is advisable from time to time, to place a PRECISION LEVEL cross-wise on the flat way to indicate and guard against tilting it. In order to raise the instrument above the leveling surfaces, a scraped PARALLEL can be set underneath, as represented in Fig. 29.36.

A procedure similar to that employed to check parallelism in the longitudinal ways of the bed is repeated now to check for OBJECTIVE NO. 2. This set up is shown in Fig. 29.37a.

Place a PRECISION CYLINDER in the V-way at one end. Then wring a number of PRECISION GAGE BLOCKS together and lay them on the flat way. After bridging across with a Scraped PARALLEL, set a PRECISION LEVEL on top. If the bubble does not center, adjust the value of the GAGE BLOCKS until it does. Then move the apparatus to the other end of the transverse ways and repeat the test. The tolerance is shown in Fig. 29.37b.

In scraping the transverse bed ways to correct alignment, we may use the set up

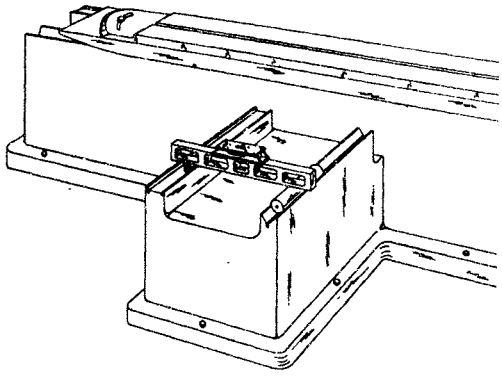

Fig. 29.37(a) View showing transverse ways of bed being checked for parallelism in vertical plane.

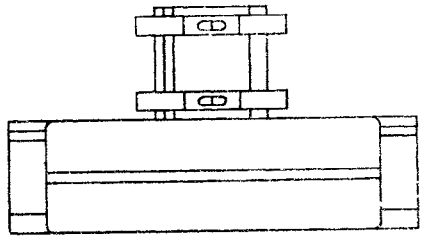

Fig. 29.37(b) Transverse bed ways - parallel in vertical plane. (No twist permitted) Max. tolerance 0.0005" per 3 feet.

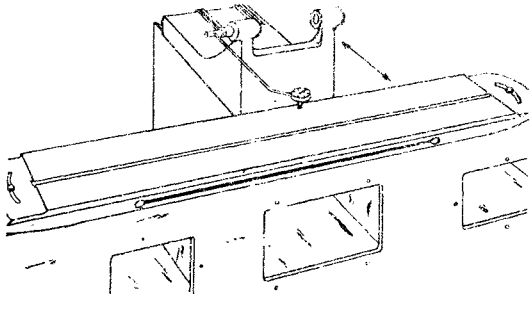

Fig. 29.38 Checking parallelism of transverse ways of bed with top of swivel plate in vertical plane.

shown in Fig. 29.38 as a preliminary test for OBJECTIVE NO. 3. This calls for placing the wheelhead in position on the transverse ways of the bed, mounting a DIAL INDICATOR on the wheelhead, and adjusting it to touch the top of the swivel plate. The wheelhead is moved in-and-out and meantime the DIAL is read. As successive tests denote a constantly improving alignment, it is advisable to switch to a more precise, though complex check.

The set up to test for OBJECTIVE NO. 3 is, therefore, changed as follows:

The workhead is swiveled to its 90° position i.e. (square with the table movement) and clamped. The tapered shank test bar previously used is inserted into the workhead spindle. A runout test is conducted and the spindle revolved until the mean position is in the vertical plane. Next a DIAL INDICATOR is mounted on the wheelhead in a position suitable for adjusting the DIAL button to touch the test bar at the vertical diameter, as shown in Fig. 29.39a. The wheelhead is moved out and in, and the reading is noted. Fig. 29.39b shows the tolerance.

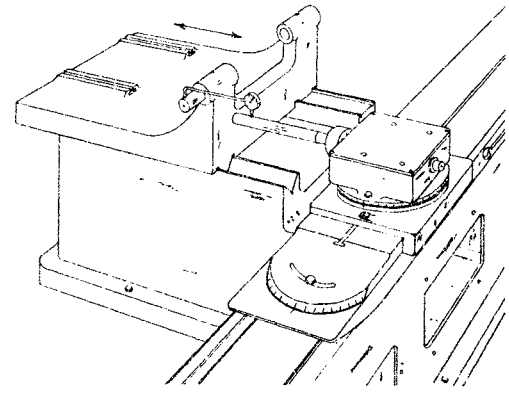

Fig. 29.39(a) General arrangement of apparatus for testing in-feed movement of wheel head for parallelism with axis of spindle of work head in vertical plane. Work head swiveled 90°.

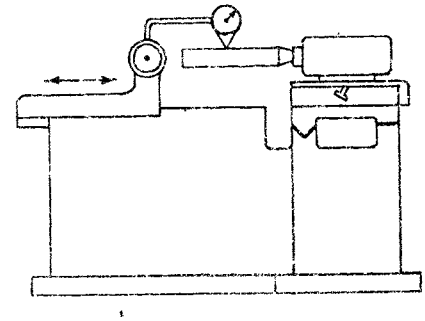

Fig. 29.39(b) Axis of spindle parallel with in-feed movement of grinding wheel. Workhead in 90° position. Max. tolerance 0 to 0.0008" per foot. (Rising towards the free end of test bar)

We test for OBJECTIVE NO. 4 by placing a SCRAPED TRIANGLE on the top of the Swivel Plate and adjusting it so one leg is parallel with the table movement. Fig. 29.40a shows the set up. An accurate

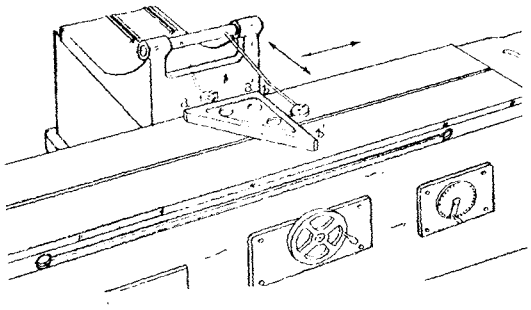

Fig. 29.40(a) View showing how transverse ways of bed are checked square with iongitudinal ways of bed.

position is assured by mounting a DIAL INDICATOR on the wheelhead and adjusting it to touch the SCRAPED TRIANGLE on the side (a – a'). The table is now moved back and forth and the TRIANGLE is adjusted so that a zero-zero reading is observed. This indicates that the side (a – a') of the TRIANGLE is parallel with the table movement. To maintain this position, the TRIANGLE is tightly clamped to the swivel plate. Without removing the DIAL from the wheelhead on which it is mounted, the button is adjusted to touch the other leg (b – b') of the TRIANGLE. The wheelhead is now moved in and out meanwhile the reading is noted. The tolerance for this alignment shown in Fig. 29.40b must not be exceeded.

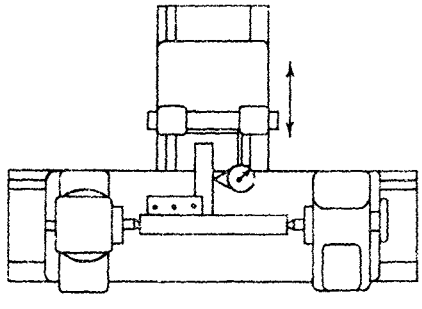

Fig. 29.40(b) In-feed movement of wheelhead square with longitudinal ways of bed. Max. tolerance 0.0004" on total length of in-feed motion.

The requisite bearing quality specified in OBJECTIVE NO. 5 is attained simultaneously with the completion of the alignment tests of the transverse ways. The quality of these bearing surfaces should not be skimped. A smooth uniform feed of the wheelhead is essential if an acceptable finish is to be ground on the work piece. Adequate bearing quality, by helping maintain constant thickness of lubricating film, prevents metallic contact and consequent jerky movements of the wheel. (Refer to Chapter 24 for a discussion of Surface Bearing Requirements of Precision Grinding Machines)

This completes the transverse ways of the bed and we turn next to the wheelhead.

Sec. 29.41
The Wheelhead

This member is supported and guided by the transverse ways of the bed. It mounts the electric motor (for motive power), the grinding wheel etc. Fig. 29.41a shows the wheelhead and its component parts. Fig. 29.41b shows the upper part

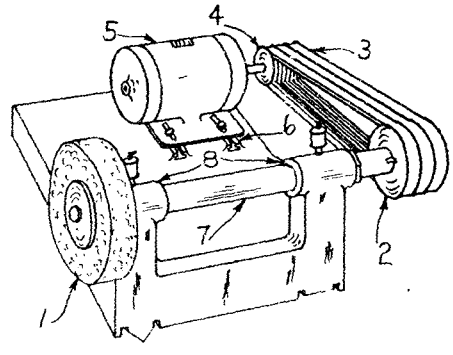

Fig. 29.41(a) The Wheelhead and attachments.

(1) abrasive grinding wheel (2) spindle pulley (3) V-belts (4) motor pulley (5) motor (6) T-slots for motor base (7) spindle (8) spindle bearings.

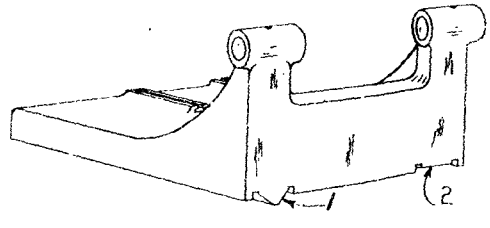

Fig. 29.41(b) The bearing surfaces of the wheelhead slide member.

(1) the inverted V-slide (2) the flat slide.

of the casting stripped of all impedimenta. The bearing surfaces of this member are denoted as follows:

1) inverted V-slide
2) flat slide

After dismantling the wheelhead, the several parts are checked for wear. The spindle in particular should be inspected and reground if out of round. At this time spindle bearings are refitted to the spindle.

Two tests will now be conducted on the spindle to determine if it is in good repair.

Sec. 29.42
Taper on Grinding Wheel Spindle for True Running.

PROCEDURE:.

The grinding wheel spindle is inserted in the spindle bearings which are then adjusted for the proper working clearance. A DIAL INDICATOR button is positioned on the tapered portion. As the spindle is revolved, a reading is taken. The tolerance indicated in Fig. 29.42a must not be exceeded.

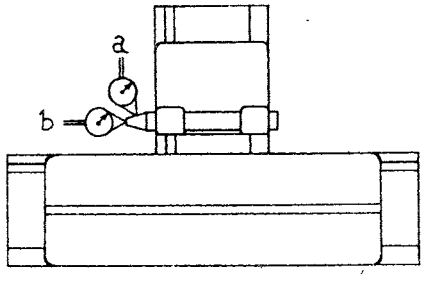

Fig. 29.42 (a) Grinding wheel spindle taper test for true running. Max. tolerance 0.0002". (b) Grinding wheel spindle test for cam action. Max. tolerance 0.0004".

Sec. 29.43
Grinding wheel spindle for Cam Action

PROCEDURE:

The DIAL INDICATOR button is now positioned against the end face of the tapered section of the spindle, and the spindle is revolved. The reading is taken at two points 180° apart on the end face. Readings should not exceed the tolerance shown in Fig. 29.42b. For supplementary material, refer to Sec. 16.11 on Cam Action.

If both of the foregoing tests are passed successfully, the spindle and its bearings are deemed in satisfactory condition. The spindle is now withdrawn and temporarily set aside.

Sec. 29.44
Preparing a Test Bar

Due to the inadequate length of the spindle, a test bar is substituted for it in the various alignment tests performed on the wheelhead. Since a suitable test bar is practically indispensable, it should be made up at this time.

The diameter of the bearing areas of the test bar must equal the diameter of the journals of the wheelhead spindle in order to match the newly fitted spindle bearings. Furthermore, it is preferable that the diameter of the target end of the test bar be precisely equal to the diameter of the target of the taper shank test bar previously utilized in aligning the workhead. This similarity is desirable because as the scraping proceeds, alignment tests will be conducted on both bars simultaneously. If the individual test bars have identical diameters, the alignment procedure is simplified.

NOTE: Collars could be made up to equalize a difference in diameters.

As a result of the two conditions mentioned above, the test bar for the wheelhead will have an appearance similar to that shown in Fig. 29.43. That is, it will be made long enough to extend 12" beyond the bearing housing and be ground to fit

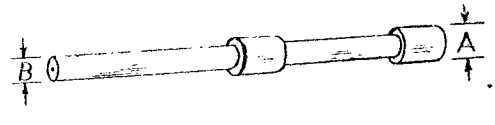

Fig. 29.43 Diagram of test bar for insertion in wheelhead spindle bearings. Target length 12". Diameter (A) equals diameter of journals of wheelhead spindle. Diameter (B) should be identical to diameter of test bar used for tests on work head.

the spindle bearings. Fig. 29.44 shows the test bar inserted in the spindle bearings.

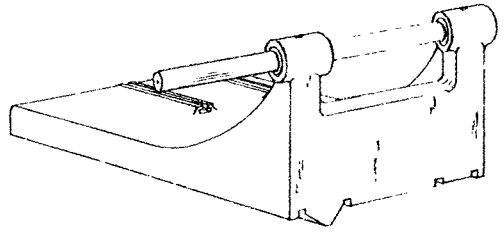

Fig. 29.44 Showing test bar inserted in wheelhead spindle bearings.

Sec. 29.45

OBJECTIVES: The Slides of the Wheelhead

1. Axis of wheelhead spindle to be parallel to table movement in vertical plane.
2. Axis of wheelhead spindle to be parallel to table movement in horizontal plane.
3. Axis of wheelhead and workhead spindles to be at the same height with reference to Swivel Plate.
4. To be fitted to the transverse ways of the bed with a surface quality of 10 – 15 bearing spots per square inch.

PROCEDURE:

Before undertaking to scrape the wheelhead member, the operator should be apprised of the difficulty involved. This is a heavy, cumbersome casting, awkward to handle. Moreover, it has several OBJECTIVES which must be attained simultaneously. But the principal difficulty is that all OBJECTIVES must be accomplished at a certain precise moment. This critical period is reached when the axis of the wheelhead spindle is at the same height as the axis of the workhead spindle in relation to the Swivel Plate. If this level is reached, or passed, before the other alignments are achieved, or adequate bearing quality provided, it will necessitate rescraping both the footstock and workhead to lower them to the new elevation set by the wheelhead spindle. Therefore, in treating the wheelhead slides special attention should be accorded this requirement.

The slides of the wheelhead are spotted on the transverse bed ways used as a template. In transferring the compound, the recommended spotting technique is to employ the shortest possible movement.

An inspection of the colored markings produced on the bearing surfaces of the wheelhead will determine how closely the slides are being fitted to the bed ways. As the scraping work proceeds, frequent checks of the alignment must be made as follows:

To test for OBJECTIVE NO. 1, the following set up is required. The test bar previously made up is inserted into the spindle bearings of the wheelhead. A DIAL INDICATOR is mounted on a stand on the top of the swivel plate with the button of the instrument adjusted to touch the test bar at the vertical diameter, as shown in Fig. 29.45. The work table is pushed back and forth on the bed ways, thus moving the DIAL INDICATOR along the test bar from (A) to (B). The unilateral tolerance allowed, is shown in Fig. 29.46a.

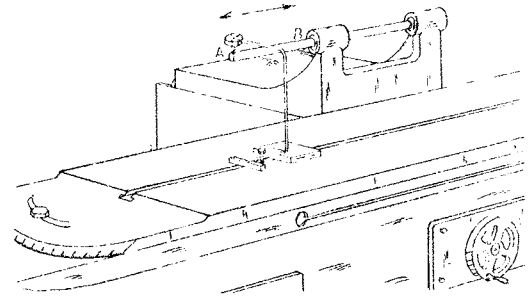

Fig. 29.45 Showing set up for testing parallelism of wheelhead spindle to table movement in vertical plane. (The horizontal plane would be tested by setting DIAL button at the horizontal diameter.)

NOTE: With this type of test bar the chief cause of error in the readings, next to grinding faults in the bar itself, is in the spindle bearings. To reduce the error to a minimum when testing with the wheelhead test bar, all measurements should be directed to, or from, the mean position of eccentricity error. Therefore, a run out test is always performed to find it. The mean position on the bar is then turned to the vertical or horizontal plane, as the occasion demands.

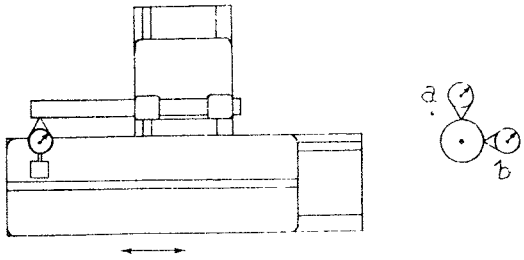

Fig. 29.46 (a) Axis of wheelhead spindle parallel with table movement in vertical plane. Max. tolerance 0 to 0.0012" per foot. (High at free end of bar.) (b) Axis of wheelhead spindle parallel with table movement in horizontal plane. Max. tolerance 0 to 0.0012" per foot. (Free end of bar inclined towards table.)

OBJECTIVE NO. 2 is tested with a set up similar to the preceding except that the INDICATOR button is now positioned at the horizontal diameter of the test bar. It is important not to exceed the tolerance shown in Fig. 29.46b.

These alignments specified by the first two OBJECTIVES must be attained simultaneously with the proper elevation of the wheelhead spindle, as indicated by OBJECTIVE NO. 3. If this condition is not brought about, the surface lines of a work piece on taper grinding will be hyperbolic instead of straight and tapered, which they should be to have a true form. Thus it will be seen that the axis of the wheelhead spindle must be "on center" with the work piece.

To accomplish this, it may be necessary to scrape a considerable quantity of metal from the bearing surfaces of the wheelhead to bring the axis of the wheelhead spindle to the same elevation now occupied by the axis of the workhead spindle. How much to remove depends entirely on the quantity of metal scraped from the members previously treated i.e. longitudinal ways of the bed, slides of table, top of table etc. Collectively they determine the new elevation of the workhead and footstock spindles which the wheelhead spindle must match. While undoubtedly some equalization occurred when the transverse ways of the bed were scraped, normally it would not amount to much because the degree of wear on these surfaces is comparatively small thus requiring a minimum of scraping. Consequently, the difference now remaining must be scraped from the wheelhead bearing surfaces. Incidentally, rough scraping should be resorted to for rapid removal of this excess metal.

To determine proximity to OBJECTIVE

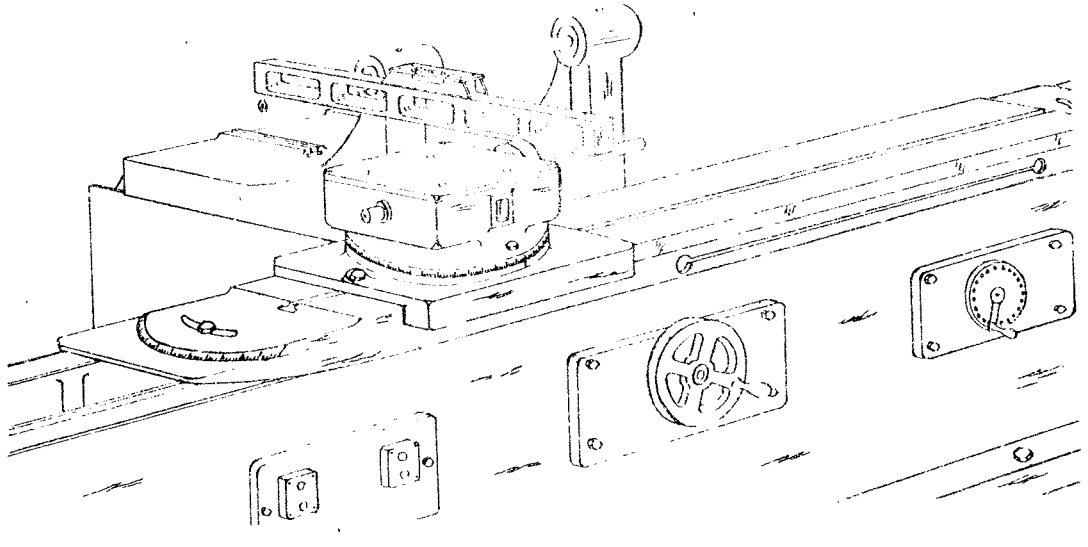

Fig. 29.47 Method of testing axes of wheelhead spindle and workhead spindle for parallelism to Swivel Plate in vertical plane.

NO. 3, the set up represented in Fig. 29.47 can be arranged. The test bar in the wheelhead bearings and the test bar in the workhead spindle are turned so that the mean position of eccentricity error of each is at the vertical diameter. A SCRAPED PARALLEL is laid across them, and a PRECISION LEVEL is placed on top. If the axis of each bar is at the same level, the bubble in the instrument will so register. (This presupposes that the diameters of the respective test bars are identical.) Fig. 29.48 illustrates the allowed error.

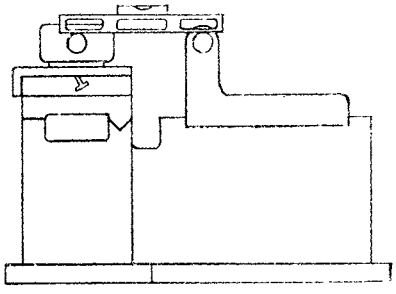

Fig. 29.48 Checking alignment of axis of wheelhead spindle and workhead for height with respect to swivel plate. Max. tolerance 0.004".

Another procedure employed in checking for OBJECTIVE NO. 3 is as follows: A Surface Gage with attached DIAL INDICATOR is positioned on the Swivel Plate. The button of the instrument is adjusted to touch the test bar, inserted in the workhead spindle, at the vertical diameter, as shown in Fig. 29.49. The DIAL is "zeroed," and then without altering the setting, the apparatus is moved over to touch the vertical diameter of the test bar inserted in the wheelhead. Fig. 29.48 again shows the tolerance.

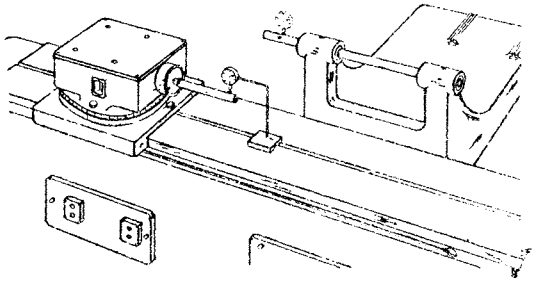

Fig. 29.49 Showing arrangement of apparatus for comparing the heights of axis of wheelhead spindle and axis of workhead spindle with reference to Swivel Plate using Surface Gage and DIAL INDICATOR.

OBJECTIVE NO. 4 is attained simultaneously with the others. As a further check of adequate bearing quality and fit, the rise and fall of the wheelhead during in-feed is tested. This test is utilized as an aid to determine if "wind" is developing in the wheelhead slides. The tolerance allowed is shown in Fig. 29.50a. The set up is as follows:

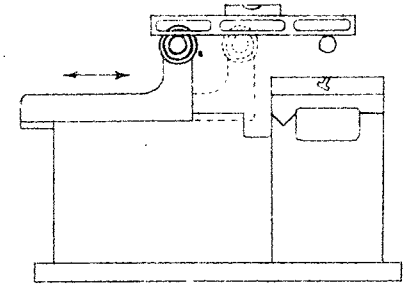

Fig. 29.50 (a) Testing rise and fall of wheelhead spindle during in-feed by means of a PRECISION LEVEL. Max. Tolerance 0.002" on total length of in-feed motion.

Back the wheelhead to its extreme rear position. Insert a test bar in the wheelhead spindle and another test bar in the workhead spindle. Adjust the workhead spindle parallel with the table movement. Place a scraped PARALLEL on the two test bars with a PRECISION LEVEL placed on top of the PARALLEL. Observe the bubble during the in-feed of the wheelhead to its extreme forward position.

Another method of checking "wind" is to position a Surface Gage with attached DIAL INDICATOR on the Swivel Plate top. Then adjust the DIAL button to touch the wheelhead test bar at the vertical diameter. One reading is taken as the wheelhead is at the extreme rear of the transverse ways. Another is taken when it is advanced to the front position of the transverse ways. Any variation in the readings should not exceed the tolerance shown in Fig. 29.50b.

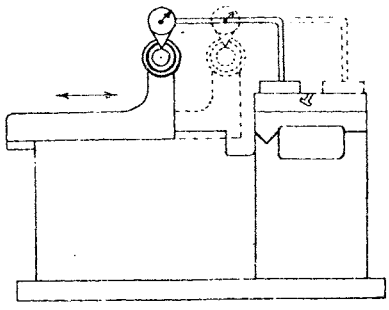

Fig. 29.50 (b) Testing rise and fall of wheelhead spindle during in-feed using a Surface Gage and attached DIAL INDICATOR. Max. tolerance 0.002" on total length of in-feed motion.

GAGE BLOCKS at one or the other end till the bubble centers. The difference in value between the two sets of GAGE BLOCKS indicates the amount of deviation of the axis from the vertical plane.

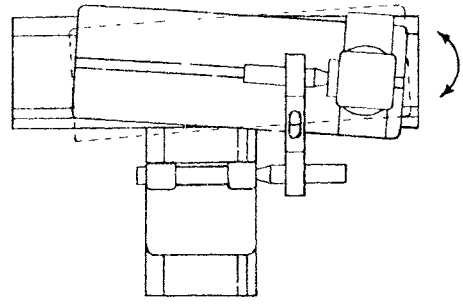

Fig. 29.51 Testing Swivel Plate for taper grinding. Max. tolerance 0.004".

Sec. 29.46
Taper Grinding

As explained previously, the function of the swivel plate is to swivel the work piece in order to grind tapers. Two conditions must be satisfied before the ground taper will be accurate, that is, have its surface lines straight and tapered. The most obvious requirement, and one for which tests have just been concluded, is that the axes of the wheelhead spindle and the workhead spindle be at the same elevation.

The second requirement is that the axis of the workhead spindle must remain horizontal when the swivel plate is swung its maximum distance to each side of center. Any deviation from the horizontal as the swivel plate is obliqued will cause the surface lines of the work piece to be ground hyperbolic.

To test how accurately the members have been scraped, a set up similar to that shown in Fig. 29.47 can be used. One slight difference is that precision GAGE BLOCKS are interposed between the two identical diameter test bars inserted in the spindles and the PARALLEL which is laid across. A PRECISION LEVEL is mounted on top.

An accurate condition is indicated if the bubble in the vial remains centered as the Swivel Plate is swung its extreme limit each side of center. A deflection of the bubble indicates an error. The exact degree of error is determined by adding

If the tolerance shown in Fig. 29.51 is exceeded, the fault will be that the top of the work table is not level. This surface should be retested according to the procedures already given.

From the rather liberal tolerance permitted on this alignment it is apparent that deviations in the form of the ground pieces from the true taper are noticeable only with far larger variations in elevations of the axes.

Sec. 29.47
Detecting Isolated High Spots

After the wheelhead slides are completed, the wheelhead should be removed from the bed. The transverse ways of the bed are now coated thinly with a light film of marking compound. After replacing the wheelhead, the member is pushed and pulled the full length of the bed ways a number of times so that a complete and thorough marking will occur. The purpose of this action is to reveal isolated high spots which have so far escaped detection by ordinary spotting techniques. They will be indicated by black or shiny streaks. Their removal is effected at the same time the ways and slides are touched up which process will now be described.

Sec. 29.48
Touching Up the Ways

The touching up process consists of

sub-dividing concentrated groupings of bearing spots appearing on the longitudinal ways of the bed and table slides and on the transverse bed ways and wheelhead slides. These areas are now clearly visible and identifiable as shiny black spots or streaks. This distinctive coloration is formed by repeated movements of the table and wheelhead, as each member is slid back and forth on the bed during the various alignment tests. Preparation was made for this result by coating the bed ways with a film of marking compound as described in Sec. 29.18 and Sec. 29.47. (Refer also to Sec. 6.17)

Touching up will in nowise affect the alignment of the members. This scraping process removes only a trifling amount of metal, and that of microscopic thickness. Its sole effect is to improve the bearing quality of the surfaces.

After the ways of the bed are touched up they should be cleaned of all traces of marking compound and grit. This may seem a superfluous instruction, yet the hurried or careless worker often forgets.

Sec. 29.49
Oiling Wheels

Oil holes and oil lines are flushed of foreign matter and the oil wells in the bed ways are filled with lubricant. The oiling wheels are now inserted into the wells and inspected for clearance below the level of adiacent bearing surfaces. This is done by laying either a hardened steel STRAIGHT EDGE or a SCALE across the rims of the oiling wheel, thereby spanning the oil well.

The oiling wheels are adjudged correctly positioned if two conditions are satisfied, namely:

1. The weight of the STRAIGHT EDGE depresses the rim of the oiling wheel to the level of the adjacent bearing surfaces.
2. The oiling wheel can be pushed even farther down by light finger pressure. Both rims should depress with equal ease. Otherwise, a bind is indicated, and the slides may be held from full area contact with the bed ways.

Sec. 29.50
Checking Back Lash

After cleaning the table, it is refitted with the rack. The table is then placed in position on the bed and the back lash between the rack and pinion is checked. Back lash in the pinion, if readily apparent, is assurance that the table is in full contact with the bed. However, an excessive amount is undesirable. About .008" to .015" is acceptable. (Refer to Sec. 22.21 Checking Back Lash.)

Absence of back lash suggests that the rack and pinion are too tightly meshed and that perhaps the table slides are not in full contact with the longitudinal ways of the bed. This is a likely possibility if a large quantity of metal has been scraped from the bed ways and table slides. Since the position of the pinion is unchanged, the removal of this metal lowers the rack directly upon the pinion. To permit the desired amount of back lash between the rack and pinion, the excess of metal can be removed from the flat side of the rack by grinding etc.

Additionally, the Light Test described in Sec. 18.11 should be applied to assure that all non-bearing projections on the table clear the bed.

After the other members are cleaned and assembled, the reconditioning of the cylindrical grinder is considered completed. Several Working Tests are now conducted on the finished machine to determine the accuracy with which the Static Tests have been performed. In preparation for this it is always good practice to run in the machine under power for about one hour. During this warming-up period the various members are repeatedly tested for quietness and smoothness of movement. When the machine attains a constant, normal, operating temperature the Working Tests may be executed.

Sec. 29.51
Working Test
Machine Grinds Round

PROCEDURE:

Mount the work piece in a chuck. Select a grinding wheel of the largest permissible diameter. It should be well dressed. The tolerance allowed for this test is shown in Fig. 29.52.

Fig. 29.52 Working test: Machine grinds round.
Max. tolerance for stock up to 3" - 0.00012"
Max. tolerance for stock up to 8" - 0.0002"
Max. tolerance for stock over 8" - 0.0004"

Sec. 29.52
Working Test
Machine Grinds Cylindrically

PROCEDURE:

The work piece is mounted between dead centers and without steady rests. The tolerance allowed is shown in Fig. 29.53.

Fig. 29.53 Working test: Machine grinds cylindrical (without steady rests)

Shafts 40" by 3"	0 to 0.0008"	convex only
Shafts 20" by 2"	0 to 0.0004"	convex only

Sec. 29.53
Working Test
Wheelhead Approach to Work

PROCEDURE:

With the grinding wheel lightly sparking out against the work piece, back away the wheelhead. Then move it forward to its original position, as determined by the feeding mechanism. The degree of sparking should be the same. Repeat six times. This is a visual test but is considered accurate.

The factors which may influence results are not alone the condition of the bearing surfaces. For example, the graduated cross-feed mechanism of the hand wheel, an inaccurate feed screw, inadequate oil film, all may affect the precise return of the wheel to the work. Failure of the wheel to revert to its exact starting point is evidenced by a change in the degree of sparking.

Should this test be made with a DIAL INDICATOR the permissible tolerance can be found in Fig. 29.54.

Fig. 29.54 Working test: Wheel head approach to work. Quick approach six times 0.0001"

Chapter 30

PRECISION GRINDING MACHINES

THE SURFACE GRINDER

Surface grinders are precision machines capable of grinding flat surfaces to an extremely high degree of accuracy. They have been developed for many special purposes hence various models and types are available.

Surface grinders may be grouped generally into those having a reciprocating work-table and those having a rotary work-table, though some special machines have both kinds.

The above classification may be further sub-divided according to the type of wheelhead spindle. Those having vertical spindles are particularly effective for grinding work pieces of large area. This type is intended chiefly for wet grinding. For smaller work surfaces including tool-room grinding, the machines are equipped with a horizontal spindle and are in the main dry grinders.

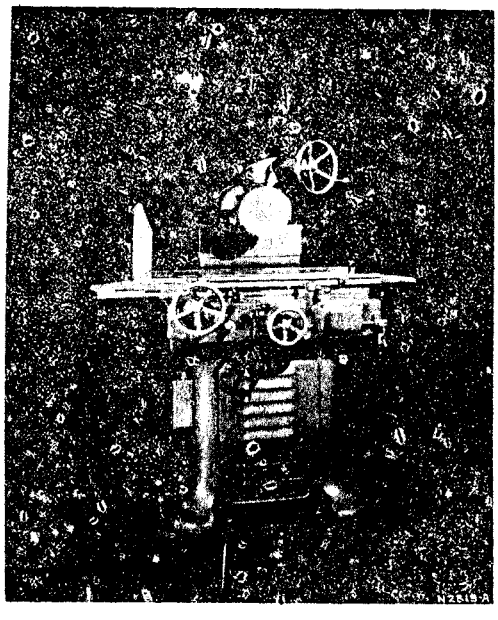

PLATE 60. Norton surface grinder completely assembled after tests and inspection. (Courtesy - The Norton Company)

Each class may be designed for automatic feed, though the smaller machines are usually hand fed.

In operation, the work piece is clamped to the reciprocating work-table, or held by a magnetic chuck fastened to the table, and is drawn back and forth beneath a rotating abrasive wheel. The table thus executes a longitudinal movement. Grinding is performed during both right and left travel of the work-table.

With the smaller machines the out-and-in movement of the carriage-table assembly provides a transverse adjustment to the work piece.

Adjustment for depth of cut is provided by a vertical movement of the wheelhead housing.

On the larger machines both the transverse and vertical movements are usually performed by the wheelhead assembly.

In a class by themselves are surface grinding machines having a rotating table. In one type, the work-table is centered in a horizontal position on top of a vertical spindle. The abrasive wheel spindle is also vertical, and the grinding is done by the flank of the wheel. Continuous loading of piece parts is possible though it is also practicable to load, grind, and unload in batches.

Another type of rotary table surface grinder has a horizontal table which rotates on a vertical spindle and carries the work-piece under the grinding wheel. Provision may be made to tilt the work-table and its spindle, in order to grind bevels, reliefs or concaves. The entire work-table assembly is mounted on slides and feeds vertically toward the wheel. The wheelhead housing reciprocates on horizontal slides.

Rotary table surface grinding machines designed for high production frequently have two or more vertical wheel spindles, so that the work may be rough- and

finish-ground during one revolution of the table. These grinders are definitely special-purpose machines.

Sec. 30.1
The Plain Surface Grinder: Components

The precision machine with vertically adjustable horizontal grinding wheel spindle, illustrated in Fig. 30.1, is generally

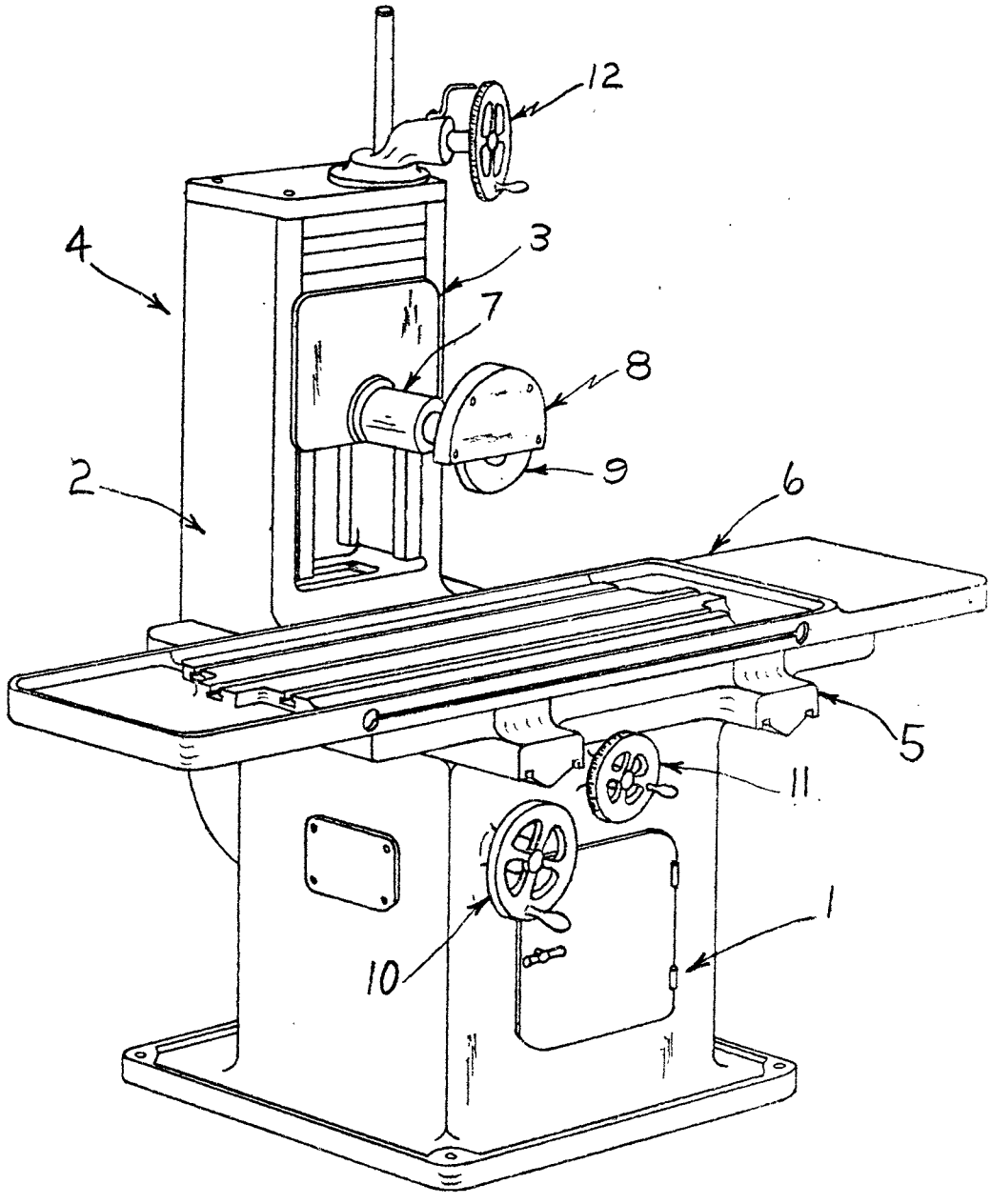

Fig. 30.1 View of the principal parts of the plain surface grinding machine.

(1) bed (2) upright (3) wheelhead housing (4) rear bracket plate (5) carriage (6) work-table (7) spindle cartridge (8) wheel guard (9) grinding wheel (10) hand wheel - longitudinal movement (11) hand wheel - transverse movement (12) hand wheel - vertical movement

classified as a plain surface grinder. It has five principal members which must be scraped and aligned by the scraping operator when the need for reconditioning is shown. They are enumerated as:

1. The Bed (1). The base casting of the surface grinder is usually called the bed. In form it is a square member made from cast iron or semi-steel. For bearing surfaces the bed utilizes one set of ways extended in a transverse direction. These bed ways support and guide the carriage member and are known as the transverse bed ways.
2. The Upright (2). As the name suggests, this is a vertical form of construction located at the rear of the bed. On some machines this part is bolted and pinned to the bed; on others, it is an integral part of the casting. The upright is provided with bearing surfaces referred to generally as the upright ways. These ways support and guide the wheelhead housing as it is adjusted in a vertical direction.
3. The Wheelhead Housing (3). This component is provided with bearing surfaces to mate with the upright ways hence is capable of vertical adjustment. The wheelhead housing mounts the grinding wheel. The spindle of the grinding wheel is frequently designed for belt drive, though it may be direct motor driven. In the latter case, the spindle is essentially an integral extension of the driving motor shaft.

3(a) The Rear Bracket Plate (4). To support the rear end of the wheelhead housing and provide sliding contact with the upright ways is the function of this part.

4. The Carriage (5). The member guided out-and-in by the transverse ways of the bed is termed the carriage. It is a complex casting made sufficiently large to overlap the bed ways and thus to provide them with protection from flying grit. This component is characterized by two groups of bearing surfaces, viz:

   a) Underneath is a set of slides i.e. carriage slides, on which the member is guided in the transverse direction by the bed ways.

   b) On the top surface of the carriage are the ways i.e. carriage ways, which guide the work-table in a longitudinal direction.

5. The Work-Table (6). Easily recognized by its long, thin, rectangular shape is the work-table. This member has slides i.e. table slides, providing a longitudinal movement on the ways of the carriage.

   The top surface of the work-table, designated the working surface, supports the work piece or a magnetic chuck. Incorporated in the table top are T-slots for securing the work piece. It might be worthy of mention to observe that the top surface is not scraped but is ground in-place as the final operation of the reconditioning process.

Sec. 30.2
Variations in Design of Surface Grinders.

The alert reader will notice that the design of the machine selected as a model to explain the reconditioning process on plain surface grinders, generally, may not correspond in some particulars with the make he is familiar with. Prominent distinctions observed will be in the form of the transverse ways of the bed and the method of guiding the carriage.

Among a representative group of surface grinding machines there will be also some variation in the shape of the upright, and in its length, width etc.

There is no uniformity either in the design or dimension of the wheelhead housing or in the method of attaching this member to the upright. For instance, the model we are discussing has no provision for adjusting sliding tension.

On other machines the wheelhead housing is provided with taper gibs or flat gibs to maintain proper sliding tension.

These differences notwithstanding, the following discussion will be found entirely practical and appropriate for many kinds of Plain Surface Grinders.

In general, the alignment tests required of the several members will be similar regardless of the form assumed by these members in different constructions.

Sec. 30.3
Surface Finish as a Criterion of Spindle Accuracy.

Inasmuch as any plain surface grinder is only as accurate as its spindle, good practice favors executing certain tests to determine this question before dismantling the machine.

For the first test the following simple preparations should be made. Select and mount an abrasive wheel of the proper grade and grit and dress it carefully with the diamond. Position the designated sample work piece on the magnetic chuck and grind it. Both rough and finish grinds should be performed. From an examination of the results an indication of the truth of the spindle and its bearings can be obtained.

If the surface quality and finish of the ground portion are commensurate with the work to be performed by the machine, the spindle and its bearings are shown to be in acceptable condition. The inability of the machine to grind flat and parallel due to wear in the ways and slides, will not nullify the validity of the above test.

Should the surface quality be unacceptable, then repair or substitution of the spindle and spindle bearings will be necessary.

The surface quality spoken of above is not to be confused with the longitudinal stripes appearing on the finished surface of the ground piece. These stripes are formed because the grinding wheel always turns in one direction while the grinding is done during both right and left travel of the table. Consequently, the ratio between surface speed of work to wheel speed varies on adjacent cuts. Where the paths of the wheel overlap, a third stripe is also observed. This striping is entirely a matter of the reflection of light and is too small to measure practically.

Sec. 30.4
Proving the Accuracy of the Spindle by Static Tests.

Two additional tests should be performed on the spindle to determine its accuracy. One checks the taper of the wheel spindle for true running. The other checks the wheel spindle for cam action. The accuracy required for each is shown in Fig. 30.19, (a) and (b), respectively.

Should the tolerance be exceeded in either of these tests the spindle must be removed from the spindle cartridge and repaired. This may involve regrinding the spindle, or replacing its radial bearings, or both. This adjustment can be taken care of while the slides and ways of the machine are being scraped and aligned. The accuracy of the repair work on the grinding wheel spindle can be verified at the work bench by repeating the tests for taper and cam action.

Sec. 30.5
Leveling the Plain Surface Grinder.

The next step in the program is to level the grinding machine. The leveling operation should be performed from the upright ways. This is done in two steps, viz:

1. Hold a precision ground angle plate or a TRY SQUARE against the right hand side of the front ways, as at (a) in Fig. 30.2. A PRECISION LEVEL is placed on top. The position of the bubble in the glass vial is then noted.
2. Hold the angle plate against the near side of the right hand inner ways, as at

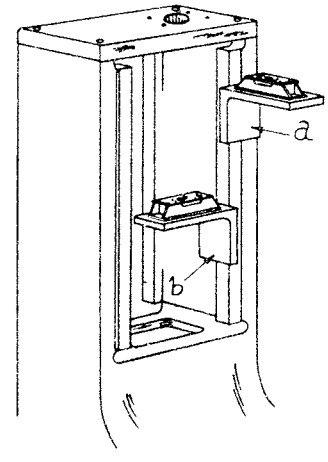

Fig. 30.2 Showing method of leveling the plain surface grinder using precision ground angle plate as a base.

(a) testing from right hand front outer way of upright (b) testing from right hand inner way of upright.

(b) in the same figure. Place a PRECISION LEVEL on top. Notice the position of the bubble in the glass vial.

These observations should be made successively and repeatedly at both positions meanwhile shimming the casting. Every effort should be made to adjust the upright so it is vertical. Achieving this condition will facilitate aligning operations on other members.

Sec. 30.6
Exploratory Examination

The work-table, carriage, and wheelhead housing should be thoroughly examined when removed. Comprehensive information concerning the condition of the bearing surfaces can be gained from this Exploratory Examination. Should the foregoing seem somewhat obscure, the reader should refer back to the discussion of this topic given in Sec. 23 3.

Associated gearing, feed screws etc. should also be removed at this time. Incidentally, after being inspected, repair or replacement of these smaller parts can be made by the machine shop while scraping is in process on the sliding bearings.

In many cases, particularly if much metal must be removed, it is wiser to postpone this operation until the bearings are scrape-finished even if it entails some delay in getting the machine back into working order. The advantage of deferring the machining job lies in the fact that it ensures against poorly meshing gears, binding of shafting etc. This procedure is doubly wise if the bearing surfaces are not lowered to a plane parallel to the original factory-new surface. Refer to Sec. 23.20 for further details.

Next the bed casting and upright member, shown in Fig. 30.3, are cleaned of all grit and oil. We are now ready to commence the scraping and aligning procedure on the plain surface grinder.

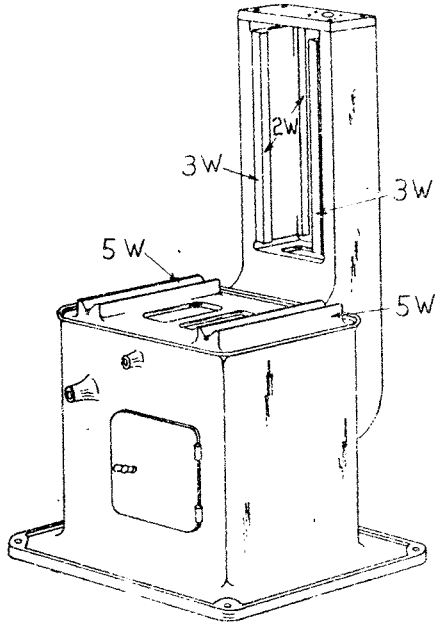

Fig. 30.3(a) Showing principal features of upright member and bed.

(2W) left hand inner ways of upright (3W) front outer ways of upright (5W) transverse Vees of bed.

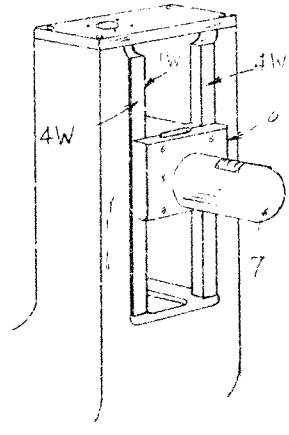

Fig. 30.3(b) Showing back view of upright and wheelhead housing.

(1W) right hand inner ways of upright (4W) rear outer ways of upright (6) rear bracket plate of wheelhead housing (7) driving motor of wheelhead

Sec. 30.7
Schedule of Operations.

Scraping operations on the plain surface grinder could be handled in several different ways but one efficient system is to treat the various members in the same order that they are enumerated, viz:

1. upright member
2. wheelhead housing
   (a) rear bracket plate

3. bed casting
4. carriage member
5. work-table

Besides the operations performed on the several members listed above, additional work is required in preparing special tools, templates, test bars, gages etc. to verify the alignment of these members. Though supplementary in nature, this work is nonetheless indispensable if accurate results are to be had.

Sec. 30.8
The Upright

In the model under discussion (See Fig. 30.3), it is seen that the upright ways have four inner bearings and four outer bearings. Viewing them from a station facing the machine, we note the following:

1. The pair on the right hand side within the upright member are called the right hand inner ways, also known as the inner guiding ways.
2. The pair on the left hand side, opposite and facing, are called the left hand inner ways, alternatively referred to as the inner gib ways.
3. The pair nearest the operator are called the front outer ways. They guide the front of the wheelhead housing.
4. The pair at the rear of the machine are designated the rear outer ways. They support the rear portion of the wheelhead housing.

Sec. 30.9
The Datum Point

Speaking generally, the indications of wear seen on the upright ways will be a minimum because these surfaces are well protected from flying grit. Moreover, they receive less use than the other bearing surfaces of the machine. Consequently,

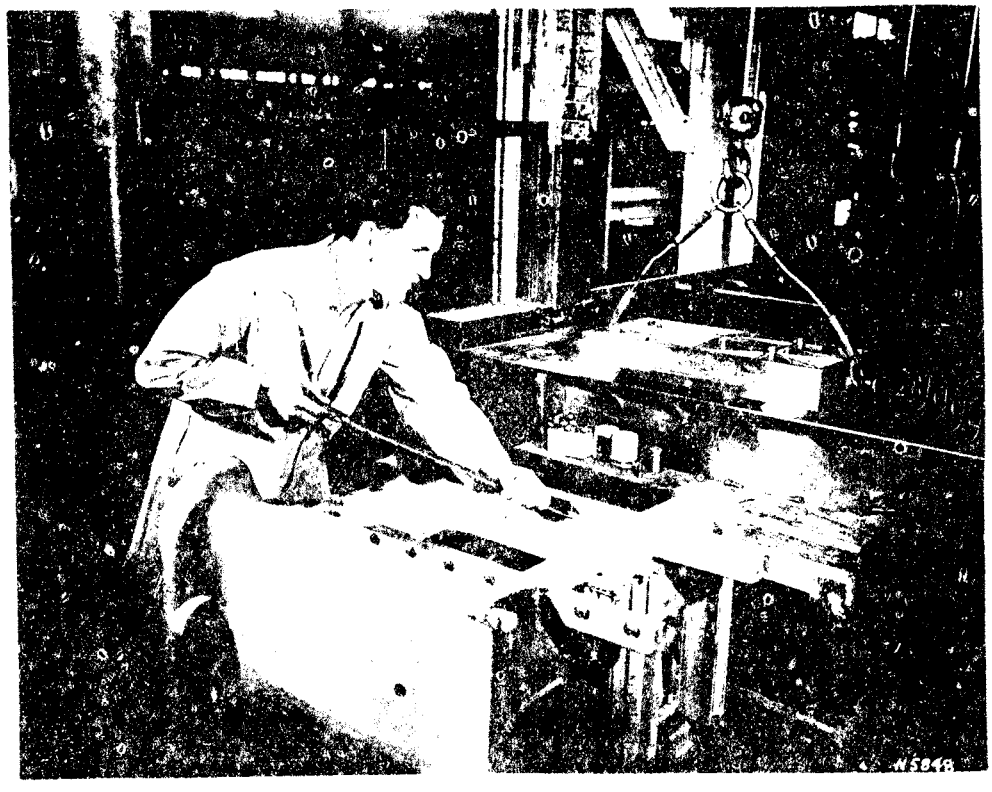

PLATE 61. Scraping the upright ways of surface grinder. The ways are spotted with the surface plate seen suspended from overhead crane in background. Note length of scraper tool used by operator. (Courtesy - The Norton Company)

as a result of their relatively superior condition, rapid progress can be made and the Datum Point quickly perfected.

Of the several pairs of ways comprising the upright member, the front outer ways are selected as the Datum Point for the other members and surfaces. The reason for the choice is that they are most accessible to the other surfaces for purposes of alignment testing.

Ordinarily, the Datum Point would be scraped at once. Though this would be entirely feasible, it is preferable, in the present situation, to start with the two pairs of inner ways. This routine is adopted because the inner ways, owing to their interior position, will be more difficult to scrape than the outer ways. They should, therefore, receive initial treatment making them a Temporary Datum Point or Check Point. Should the foregoing seem somewhat obscure, the reader is referred to Sec. 23.6 for clarifying details.

Sec. 30.10
Making a Special SURFACE PLATE for the Upright Ways.

In order to deal successfully with the upright ways, it is advisable to make up a special SURFACE PLATE. The dimension of this gage will vary according to the size of the surfaces it is designed to spot.

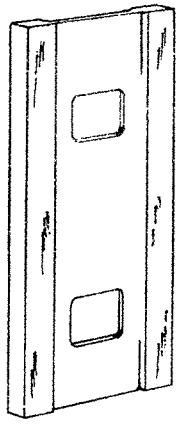

Fig. 30.4 View of special SURFACE PLATE for spotting the upright ways.

Since the spotting of the upright ways must necessarily be performed while the member is in the vertical position, a prime consideration for the tool should be light weight, as this simplifies handling. A flat steel plate without ribbing and with one side scraped to a SURFACE PLATE quality will suffice. The design shown in Fig. 30.4 is entirely practicable.

A study of the upright member shows the gage must be long enough to reach from top to bottom and wide enough to span the outer ways. Such a gage will be adequate also for the inner ways which are closer together. Having this tool available, we are now equipped to treat the ways of the upright member expeditiously.

Sec. 30.11
OBJECTIVES: The right hand (guiding pair) inner ways of the upright.

1. To be perpendicular.
2. To be parallel.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

For the initial operation the taper pins and bolts holding the upright to the bed casting should be tested for a loosened condition. Being satisfied with the rigidity of the upright, treatment of this member may be commenced.

The gage to use for spotting these surfaces will be the special SURFACE PLATE described previously. To insure maximum accuracy on this job, the operator is urged to follow the spotting instructions given in Sec. 9.4.

Scraping operations on this member will likely prove to be somewhat difficult also due to the fact that these bearings are positioned vertically and, moreover, are situated in a confined location. In spite of this handicap, every effort should be made to scrape "straight down" as this results in the removal of a minimum of metal. Other advantages of scraping these surfaces in a plane parallel with the original factory surface have been discussed at length in Sec. 23.21.

There is some danger of rounding the edges with the scraper blade thereby reducing the already quite narrow bearing area. Only careful handling of the tool can prevent this.

A small deviation from the perpendicular which may occur as a result of the scraping process is permissible if it does not exceed .002" per foot. To determine this question, checks should be made periodically during the scraping process using the set up shown in Fig. 30.2. This drawing is largely self-explanatory.

The figure shows a precision ANGLE PLATE positioned against the bearing surface and a PRECISION LEVEL placed upon it. In case the bubble is centered indicating levelness, OBJECTIVE NO. 1. is achieved.

If the final spotting cycle with the special SURFACE PLATE reveals a uniform coloration and distribution of bearing spots, it implies that OBJECTIVE NO. 2 is attained. No other test for parallelism between the pair of right hand (guiding) inner ways is needed.

OBJECTIVE NO. 3 is also realized provided the indicated bearing quality is adequate. Obviously, all OBJECTIVES must be fulfilled at the same time.

Sec. 30.12
OBJECTIVES: The left hand (gib pair) inner ways of the upright.

1. To be parallel to the pair of right hand ways opposite.
2. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The spotting and scraping operations on the left hand pair of the inner ways are similar to those adopted for the right hand pair of inner ways discussed earlier. However, these procedures must be interrupted periodically in order to conduct checks for parallelism between the right hand and left hand pairs.

A suitable tool for measuring parallelism would be the inside micrometer applied between left hand pair of inner ways and right hand pair of inner ways at the front of the machine at top and bottom. The measurement is repeated between the left and right inner ways at the rear of the machine, again at both top and bottom. In all cases dimensions between any two points must not vary more than .0005".

Sec. 30.13
OBJECTIVES: The Front pair of outer ways of the upright.

1. To be square with the right hand pair of inner ways.
2. To be parallel.
3. To be perpendicular.
4. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

Operations on the front pair of outer ways of the upright are somewhat easier to perform than on the inner ways just completed. Spotting is conducted with the special SURFACE PLATE mentioned previously. This process should be supplemented, during alternate cycles, with a Right Angle Template to keep the front pair of outer ways square with the right hand pair of inner ways. Only the right hand front way needs to be squared up. (See Fig. 30.5) The alignment of the left hand front way results automatically as the other OBJECTIVES are attained.

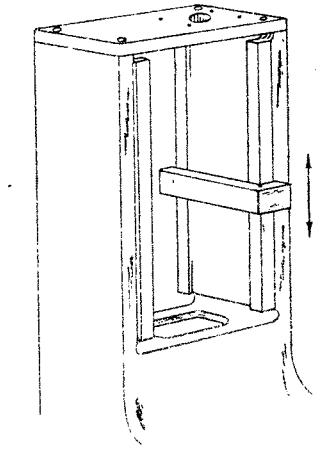

Fig. 30.5 Using a RIGHT ANGLE TEMPLATE to check squareness of front outer ways to inner ways of upright.

OBJECTIVES NO. 1 and NO. 2 are deemed accomplished when the markings produced by the Right Angle Template on the one front way correspond with the markings produced on both front ways by the special SURFACE PLATE. In other words, analysis and comparison of the

markings must reveal similar coloration and distribution of markings when produced by either method.

As a means of maintaining the original relationship with the feed screw and gearing associated with the wheelhead housing, all scraping should be executed "straight down". For further details on this process refer to Sec. 23.20.

Tests for OBJECTIVE NO. 3 are conducted periodically as the scraping progresses. A simple and rapid set up to check this condition is shown in Fig. 30.2. As an alternative, the blade of a Tool Maker's Square can be held against each of the front outer ways in turn. In each position a PRECISION LEVEL is laid on the beam of the Square. If the bubble in the glass vial is centered in both cases, the front pair of outer ways of the upright is perpendicular. A tolerance of .002" per foot is allowed.

The final spotting cycle should disclose a uniform coloration and distribution of markings overall, to denote the fulfillment of OBJECTIVE NO. 4.

The several OBJECTIVES should be completed simultaneously. The Datum Point having been established, all future alignments will be made to it.

Sec. 30.14
OBJECTIVES: The rear pair of outer ways of the upright.

1. To be parallel to the front pair of outer ways of upright.
2. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

In dealing with the rear pair of outer ways, the operations of spotting and scraping are performed alternately in the customary manner. The special SURFACE PLATE mentioned earlier is again employed for spotting purposes. The Right Angle Template is also used alternately to assist in keeping the rear outer ways square with the inner ways and hence parallel with the front outer ways.

After a few cycles of this routine, during which the bearing quality of the ways is improved, a test can be made for OBJECTIVE NO. 1. The logical choice of tool for this purpose is an outside micrometer. Measurements are made from the front outer ways to the rear outer ways at the top and at the bottom on both left and right hand sides of the upright. A tolerance of .0005" is allowed for this alignment between all points measured.

As the rear outer ways approach this standard of perfection, continuous efforts are needed to improve the surface quality to the extent demanded. Operations should, therefore, be synchronized so as to achieve both OBJECTIVES at the same time.

This completes the scraping and alignment of the upright ways. Recapitulating, we note that, within the tolerance allowed, the outer ways are square with the inner ways, that each pair is parallel with its opposite pair and that all are perpendicular. We turn now to the job of fitting the wheelhead housing to the upright.

Sec. 30.15
The Wheelhead Housing

The wheelhead housing is a sliding member that moves vertically, guided by the upright ways. It is actuated by a feed screw connecting through a pair of bevel gears to the graduated hand wheel. Auxiliary parts of the wheelhead housing are the spindle, spindle cartridge, driving motor or pulley, and abrasive wheel, as shown in Fig. 30.1.

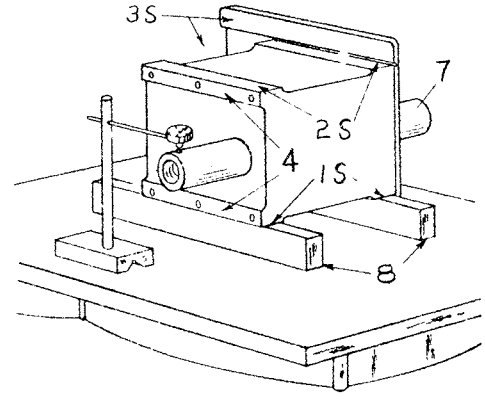

Fig. 30.6 Testing alignment of right hand slides of wheelhead housing to axis of wheel spindle.

(1S) right hand slides of wheelhead housing
(2S) left hand slides of wheelhead housing
(3S) front slides of wheelhead housing
(4) bracket bearings of wheelhead housing
(7) test bar inserted in spindle hole
(8) PARALLELS

The type of wheelhead housing under discussion must be scraped to a precise dimension allowing just the right amount of sliding clearance with the ways of the upright. Since treatment of this form involves some new procedures it will be advisable to describe them in detail in the following sections.

As Fig. 30.6 shows, the wheelhead housing has right hand (guided pair) slides (1), left hand (gibbed pair) slides (2), and front slides (3), integral with the casting. In addition to the sliding surfaces, the member is provided with bracket bearings (4) to which a bracket plate is bolted when assembly is made.

The relationship of these slides to their mating ways will be summarized to provide an overall picture of the job involved fitting this component to the upright.

1. The right hand (guided pair) slides of the wheelhead housing are fitted to the right hand (guiding pair) inner ways of upright.
2. The left hand (gibbed pair) slides of wheelhead housing are built up with steel straps. These straps are utilized to compensate for the metal removed from the inner ways of the upright and the right hand (guided pair) slides of the housing during the scraping process. After being attached they are scraped to dimension to give the housing the proper sliding fit between the inner ways of the upright member.
3. The front pair of slides of the wheelhead housing is fitted to the front pair of outside ways of the upright.
4. The bracket bearings at the rear of the housing are also scraped to dimension. The purpose of this operation is to provide the proper sliding fit for this member between the front and rear ways of the upright.

PLATE 62. Testing the fit of the slides of the wheelhead to the ways of the upright. The bearing surfaces of the upright were spotted earlier with a special template and scrape-finished. (Courtesy - Gallmeyer & Livingston Co.)

The individual problems involved in dealing with each of these groups of surfaces will now be discussed in the order enumerated above.

Sec. 30.16
OBJECTIVES: The right hand (guided pair) slides of the wheelhead housing.

1. To be parallel with the axis of the spindle.
2. To be fitted to the right hand (guiding pair) inner ways of the upright with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The very first operation in connection with the wheelhead housing is to clean it of all accumulated oil and grit. This may seem a superfluous instruction, yet a hurried or careless worker sometimes forgets with sad results.

All routine work on the right hand slides of the member in question can be conveniently handled at a work bench. Ordinarily, in "fitting" the slides, the upright ways would be used as a spotting template but in cases similar to this one equally efficient spotting can be performed with a SURFACE PLATE.

After removing the most obvious roughnesses by scraping the indicated high spots, it is best to make an immediate check of the alignment of the slides with the axis of the spindle.

A test bar is required for such a test. Specific dimensions of the bar cannot be supplied as the hole in the housing receiving the spindle cartridge varies in diameter on different machines. Furthermore, dimensions of the bar will largely depend on the kind of materials at hand. For example, if large diameter thick wall steel tubing is available, it may be ground to fit the, say, 3" hole in the

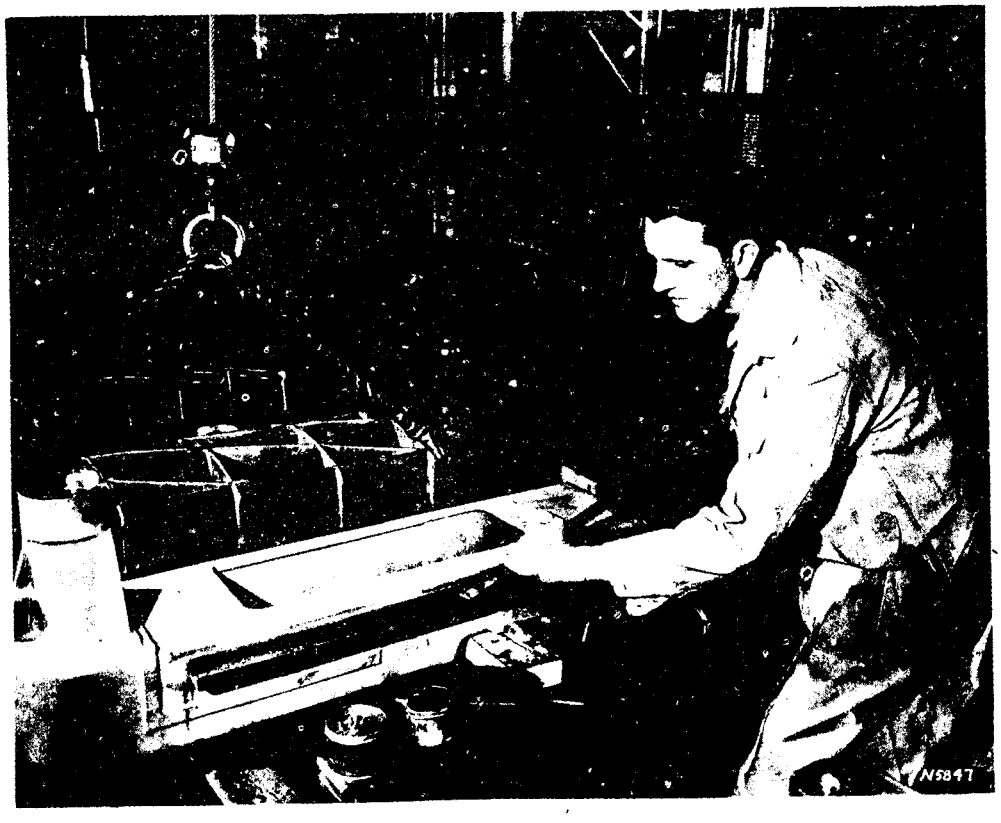

PLATE 63. Scraping the vertical slide (wheel head slides) of surface grinder. Hanging from overhead crane in background is seen the precision template used for spotting these bearings. Note spotting paraphernalia in foreground. (Courtesy - The Norton Company)

wheelhead housing. Otherwise two bushings must be made up (preferably hardened and ground to a light press fit) and inserted in the hole in the housing. The sole advantage of the latter course is that it reduces the size of the hole and thereby permits the utilization of hollow tubing or bar stock having smaller diameter.

The test bar made in one of these two forms (hollow or solid) is then ground for a sliding fit with the hole in the wheelhead housing. In either case, the test bar should be provided with a target length of 8" to 12" to make it useable for subsequent checks on other members.

To execute the test, the right hand slides of the member are placed on two identical PARALLELS laid side by side on a SURFACE PLATE. The test bar is inserted and positioned centrally in the spindle hole or in the bushings, as the case might be. Using a Surface Gage and attached DIAL INDICATOR for the purpose, measurements are made from the PLATE to the vertical diameter of the test bar adjacent the spindle cartridge hole at front and rear, as shown in Fig. 30.6. A tolerance of .0003" is permissible.

Scraping is continued on this surface until the slides are fitted to the right hand upright ways with a surface quality equal to that specified in OBJECTIVE NO. 2.

Both OBJECTIVES must be realized jointly.

Sec. 30.17

OBJECTIVES: The left hand (gibbed pair) slides of the wheelhead housing.

1. To be parallel with the right hand (guided pair) slides of the member.
2. To have a clearance of .003" between the inner ways of the upright.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The question of clearance should be the first matter investigated because the original factory-new condition no longer exists. Having removed metal from the inner ways of the upright and from the right hand slides of the wheelhead housing, we have created a situation where the housing will be too loose if inserted under present circumstances.

To take up excess slack and provide just the right amount of sliding clearance between the wheelhead housing and the inner ways of the upright, it is standard practice to fasten steel straps usually 1/8" (.125") thick to the left hand slides, securing them with countersunk 10-32 flat head screws.

Preliminary to fastening these steel straps, sufficient metal must be removed from the left hand slides of the housing to properly accomodate them. One competent method of accomplishing this is to mount the housing on a milling machine table and mill away the surplus thickness. Naturally, this is not a haphazard operation. The steps required for calculating the depth of the milling cut are enumerated below.

1. Measure the distance between the right and left hand slides of the wheelhead housing using an outside micrometer. Example — 5.000"
2. Measure the distance between the right and left hand scrape-finished inner ways of the upright, employing for this purpose an inside micrometer. Example — 5.010"
3. Clearance between members now amounts to .010".
4. Clearance for efficient operation should be only .003".
5. Excess clearance under current conditions equals .007".
6. Thickness of steel strap to be attached is, say, .125".
7. Thickness of metal to be removed from left hand slides of housing is calculated as — .125" minus .007" equals .118".
8. Allowing .005" for purposes of developing a good bearing on the steel straps, by scraping or grinding, the depth of the milling cut should be limited to — .118" minus .005" equals .113".

(The problem is shown diagrammatically in Fig. 30.7a and Fig. 30.7b)

After the slides are properly milled, drilled and tapped and the steel straps attached, spotting and scraping operations are begun with a view to satisfying all three OBJECTIVES simultaneously.

A SURFACE PLATE should be used for spotting. It will facilitate matters if a second PLATE is available to conduct

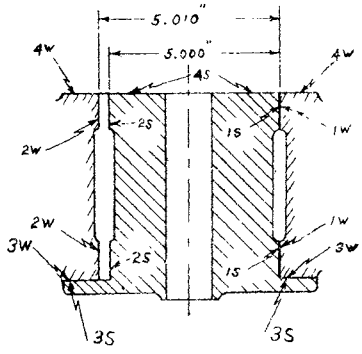

Fig. 30.7(a) Appearance of housing prior to attaching steel straps.

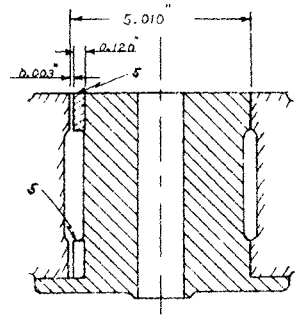

Fig. 30.7(b) Appearance of housing after steel straps are attached.

Sectional top view of wheelhead housing positioned within upright.

(1W) right hand inner way of upright (1S) right hand slide of wheelhead housing (2W) left hand inner way of upright (2S) left hand slides of wheelhead housing (3W) front outer ways of upright (3S) front slides of wheelhead housing (4W) rear outer ways of upright (4S) rear bracket bearings of wheelhead housing (5) steel straps.

the alignment tests as this eliminates some clean up time.

The set up for checking the alignment required by OBJECTIVE NO. 1 would be as follows:

Place the right hand slides of the wheelhead housing on two equal thickness PARALLELS laid side by side on a SURFACE PLATE. Position a Surface Gage with attached DIAL INDICATOR on the SURFACE PLATE. Then check to both of the left hand slides, front and back. Fig. 30.6 shown previously illustrates the testing set up.

Parallelism is indicated by a zero-zero reading. A deviation from parallelism between the slides must not exceed .0005" between any two points measured.

Useful as the foregoing set up is, it does not assist the operator in determining when the dimension listed in OBJECTIVE NO. 2 is near to being matched. To keep tabs on this essential factor it is entirely practicable to use an outside micrometer measuring from the left hand slides to the right hand slides at top and bottom.

The advantage of this method is that it warns the scraper of proximity to the critical clearance dimension, or finishing plane, thereby indicating the need for prompt development of the required bearing quality.

Arrange operations so as to accomplish the several OBJECTIVES simultaneously.

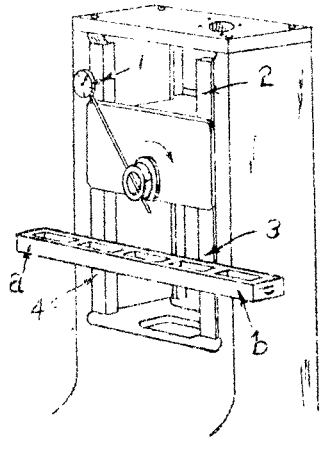

Fig. 30.8 Testing alignment of axis of wheel spindle to front outer ways of upright in vertical and horizontal planes.

NOTE:

In lieu of hand scraping the steel straps, grinding is acceptable provided an accurate surface grinding machine is available.

Sec. 30.18
OBJECTIVES: The front slides of the wheelhead housing.

1. To be square with the axis of spindle.
2. To be fitted to the front ways of the upright with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The most efficient method of spotting the front slides of this member (3) in Fig. 30.6, is to utilize the front ways of the upright as a template. Supplementary spottings can be made with a STRAIGHT EDGE to expedite the work.

We check for OBJECTIVE NO. 1 as follows: Position the housing at approximately the middle of the upright ways, as shown in Fig. 30.8, and attach the rear bracket plate. Insert sufficient shim stock between the slides of the bracket plate and the back ways of the upright so that by tightening the bolts, the front slides of the wheelhead housing can be drawn snugly up against the front ways of the upright.

The test bar mentioned previously is now inserted in the spindle hole of the housing. A rod with attached DIAL INDICATOR is clamped to the test bar.

To determine the proper alignment in the vertical plane, a swing-round test is executed. Four measurements are made at the positions designated as (1), (2), (3), and (4) in Fig. 30.8.

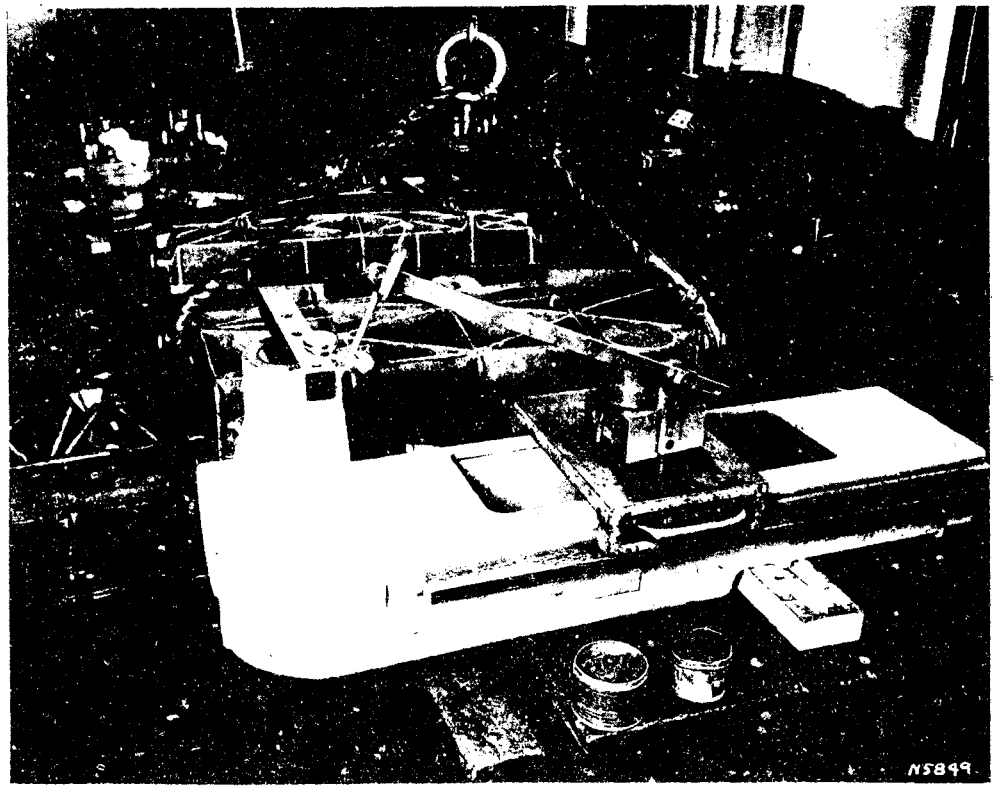

PLATE 64. Testing alignment of vertical slides of wheel head of surface grinder square with axis of spindle in horizontal plane. Inserted in the wheel head housing is a dummy spindle to which a Tee bar is permanently affixed. By moving dial indicator support across parallel sided template instrument readings are taken at both ends of the Tee bar. (Courtesy - The Norton Company)

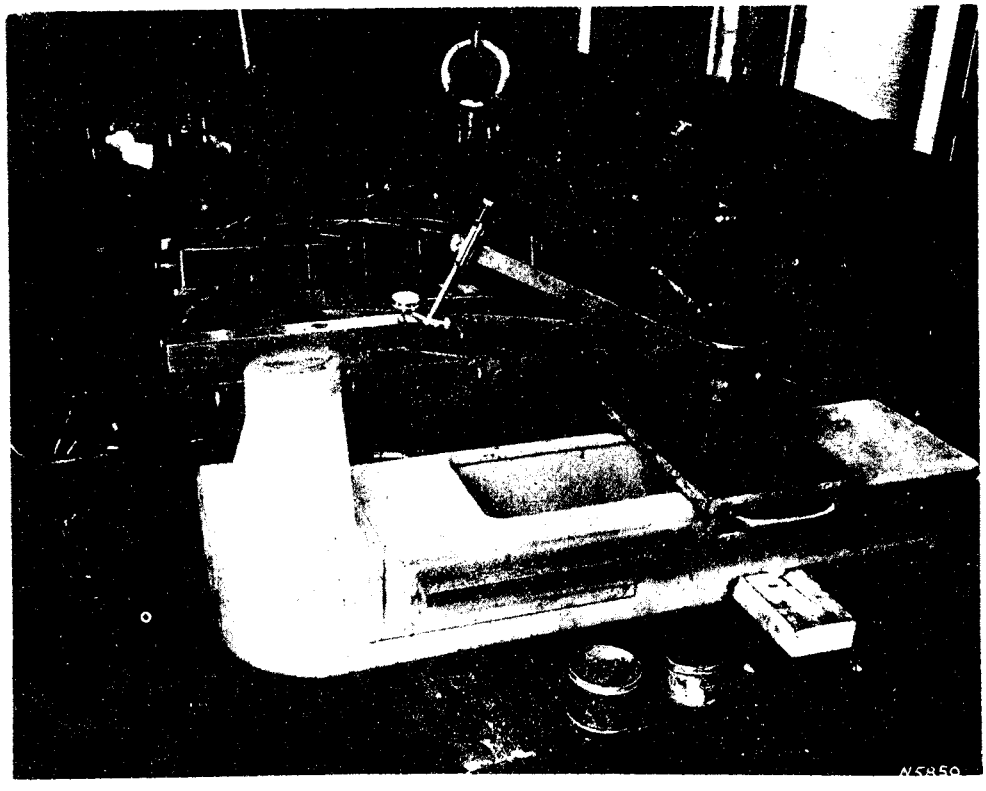

PLATE 65. Testing the alignment of vertical slides of the wheel head square with axis of spindle in vertical plane. Tee bar is rotated to vertical position. Template is moved so that readings may be obtained at both ends of bar. (Courtesy - The Norton Company)

To test the alignment in the horizontal plane the set up is changed as follows: Hold a long scraped PARALLEL against the front ways of the upright, say, below the spindle. As before, use the DIAL INDICATOR in the swing-round method to determine the alignment. Greater precision will result if contact is made on the PARALLEL at points as widely separated as possible, for example (a) and (b) the same figure.

Both tests must be repeated successively at intervals as the front slides of the wheelhead housing are being fitted.

The maximum tolerance allowed for tests in either plane is .0008" per foot.

Both OBJECTIVES are attained simultaneously.

Sec. 30.19

OBJECTIVES: The Bracket Bearings of the wheelhead housing.

1. To be parallel to the front slides of the housing.
2. To extend beyond the rear outer bearings of the upright to provide sliding clearance.
3. To have a surface quality of 5 bearing spots per square inch.

PROCEDURE:

As the first step in treating the bracket bearings of the wheelhead housing, it will be necessary to ascertain the distance from the front outer ways to the rear outer ways of the upright. An outside micrometer is utilized to measure this span.

Next the wheelhead housing is measured to obtain an idea of what is required to match this dimension. To simplify the measuring, a depth micrometer is employed. Measurements are made from the bracket bearings (4) Fig. 30.6 to the front slides (3) at top and bottom, first on one side then on the other. In addition to providing the required information, this will also indicate whether or not the

surfaces in question are parallel with the front slides as specified in OBJECTIVE NO. 1.

Having completed the essential preliminary measurements, corrective treatment of the bracket bearings of the housing can begin. Spotting should be done with a SURFACE PLATE.

The roughnesses and irregularities indicated by each spotting cycle are scraped away in the usual manner. This routine should be interrupted at frequent intervals to check for clearance.

The clearance of the housing will be adequate if it does not exceed the front to rear dimension of the upright by more than .003". That is to say, the housing inserted into position in the upright should extend beyond the rear outer bearings of the upright by .003". This represents the sliding clearance of the housing between the front and rear ways of the upright. Anything in excess of this amount should be removed from the bracket bearings of the housing member, as required by OBJECTIVE NO. 2.

Attention might be called to the minimal surface quality specified for the bracket bearings by OBJECTIVE NO. 3. Though small, it is entirely adequate because these bearings have only a stationary contact with the rear bracket plate attached thereto.

Complete all OBJECTIVES simultaneously.

Sec. 30.20
The Rear Bracket Plate.

Strictly speaking, the rear bracket plate, shown in Fig. 30.9, is a part of the wheelhead housing but to make explanation easier it is treated independently. The function of the bracket is to support the rear end of the housing member and at the same time provide means for a sliding bearing on the rear pair of outer ways of the upright.

To accomplish this dual purpose the inner half of each bearing surface of the rear bracket plate maintains a stationary contact on the bracket bearings of the housing. The outer half of the bearing surface of the rear bracket plate has sliding contact on the rear pair of upright ways.

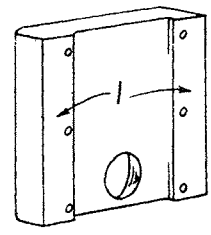

Fig. 30.9 View of Rear Bracket Plate which bolts to the wheelhead housing.

(1) slides of bracket plate

Sec. 30.21
OBJECTIVES: The Rear Bracket Plate of the Wheelhead Housing.

1. Slides to be parallel.
2. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

Treatment of the bracket plate is limited to spotting its slides on a SURFACE PLATE and scraping the indicated markings.

Both OBJECTIVES are deemed accomplished when the markings revealed by the final spotting cycle are numerically adequate, uniformly distributed, and evenly colored.

This completes all scraping and alignment work on the wheelhead housing.

Since it might facilitate subsequent operations to have the housing mounted and in operating order, attach the feed screw, gearing, and vertical adjustment hand wheel. We turn next to the problem of treating the ways of the bed.

Sec. 30.22
The Bed

The bed of the plain surface grinder, shown in Fig. 30.3, is a well ribbed casting having two transverse Vee ways on the top. Aligned square with the front outer ways of the upright, the V-ways of the bed provide means for out-and-in movement of the carriage-table assembly.

Sec. 30.23
OBJECTIVES: The V-ways of the Bed.

1. Axes of Vees to be square with the front pair of outer ways of upright in vertical and horizontal planes.
2. Axes of Vees to be parallel.
3. To have a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

A survey of the OBJECTIVES listed above does not disclose any requirement for the Vees to be at the same level or to have an equal angular value. As the reader knows, these conditions were established at time of manufacture. Conscientious application of the maxim "Scrape straight down" will reproduce a surface parallel with the original factory-new surface. It will be left to the discretion of the reconditioning expert how much to relax this rule.

In case the operator wishes to develop these factors, the following several paragraphs will provide a brief explanation of the procedure to employ.

The initial spotting operation on the transverse V-ways of the bed (Fig. 30.3) is made with a STRAIGHT EDGE. While conscientious efforts should be made to scrape "straight down", in order to keep the V-ways at the same level with each other, no precision measurements are conducted to keep tabs on this, as the accuracy of the machine would in nowise be impaired by failure so to do.

The only forseeable danger arising from neglect of this matter is that shafting, gearing etc. might become misaligned on some machines due to excessive shift in position of the bearing surfaces. This is always a possibility which the scraper must take into account. It is generally recognized as good practice to observe the rule "scrape straight down" as a means of returning the surfaces to their original alignment. In some applications it is more important than on others. Reference to Sec. 23.21 and Sec. 23.22

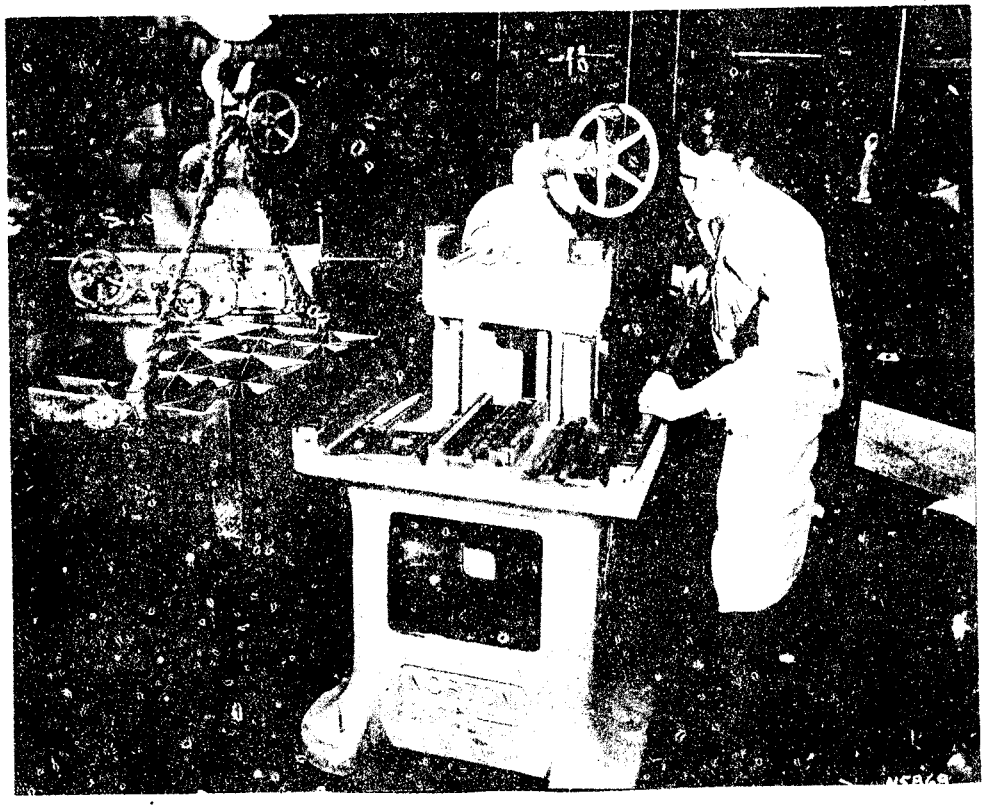

PLATE 66. Scraping the flat ways of the bed of surface grinder. Mounted on wooden horses to the left can be seen the special precision template used for spotting the bed ways. (Courtesy - The Norton Company)

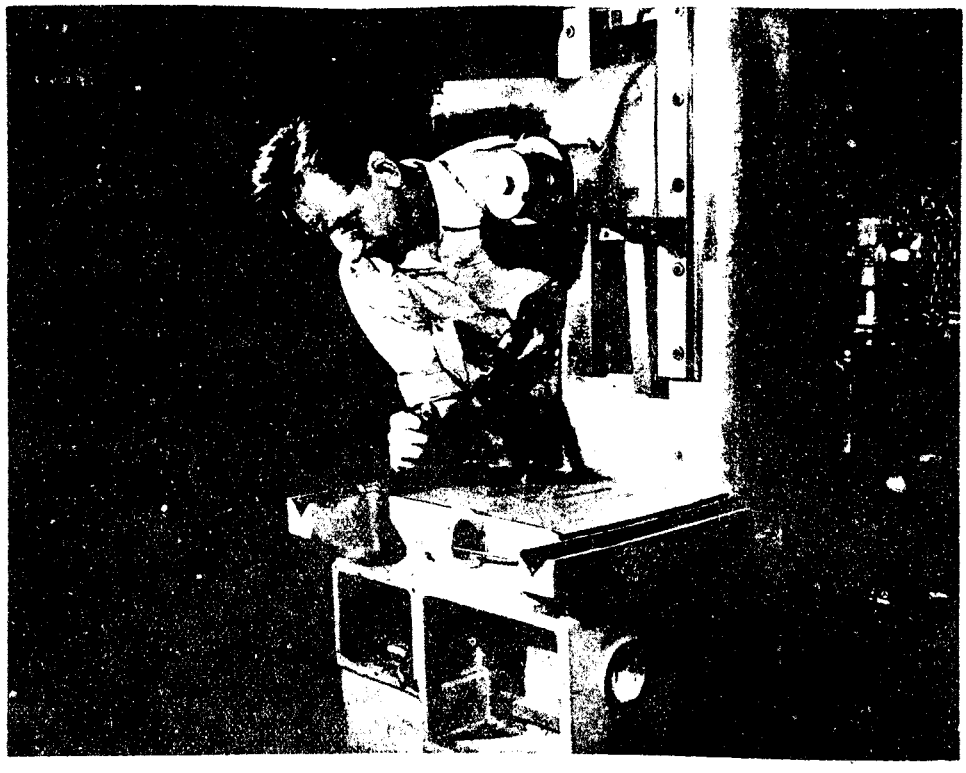

PLATE 67. Showing operator scraping in the V-ways of the bed of surface grinder. (Courtesy - Gallmeyer & Livingston Co.)

will provide the reader with more details on this important aspect of reconditioning.

An effective set up to prove that the axes of the Vees are level would require placing equal diameter PRECISION CYLINDERS in each Vee and spanning across them with a precision scraped PARALLEL on which is laid a PRECISION LEVEL. The bubble must be centered in the glass vial at all positions measured to verify this condition.

Should the V-ways be tilted slightly during the process of scraping in the desired bearing quality, it will not culminate in a faulty alignment or impaired working characteristic of the machine. Its only effect will be that one side of a particular V-way will bear a proportionately larger share of the weight than the other side. This condition causing uneven wear between the sides of the Vee is objectionable because it accelerates the rate of deterioration.

In order to equalize the wear on the Vees they must be so scraped that a perpendicular line will bisect each V-way. To accomplish this it will be necessary to construct a V-template and use it in conjunction with a PRECISION LEVEL. Before undertaking this job, it might be well to review some of the previous data contained in Sec. 12.10 and Sec. 25.14.

If the V-template is not utilized, the scraping process may cause some variation in the angular value, as between V-ways, even though measurements are carefully made with a vernier protractor. As stated before, angular variation will not affect the working accuracy of the machine.

It will be noted that the alignment specified in OBJECTIVE NO. 1 calls for tests to be made in both the vertical and horizontal planes. In the three following paragraphs, alternative set ups for measuring squareness in the vertical plane will be presented. Any of the methods described would serve the end in view but the choice for this particular job is likely to depend upon the kind of test apparatus available to the operator.

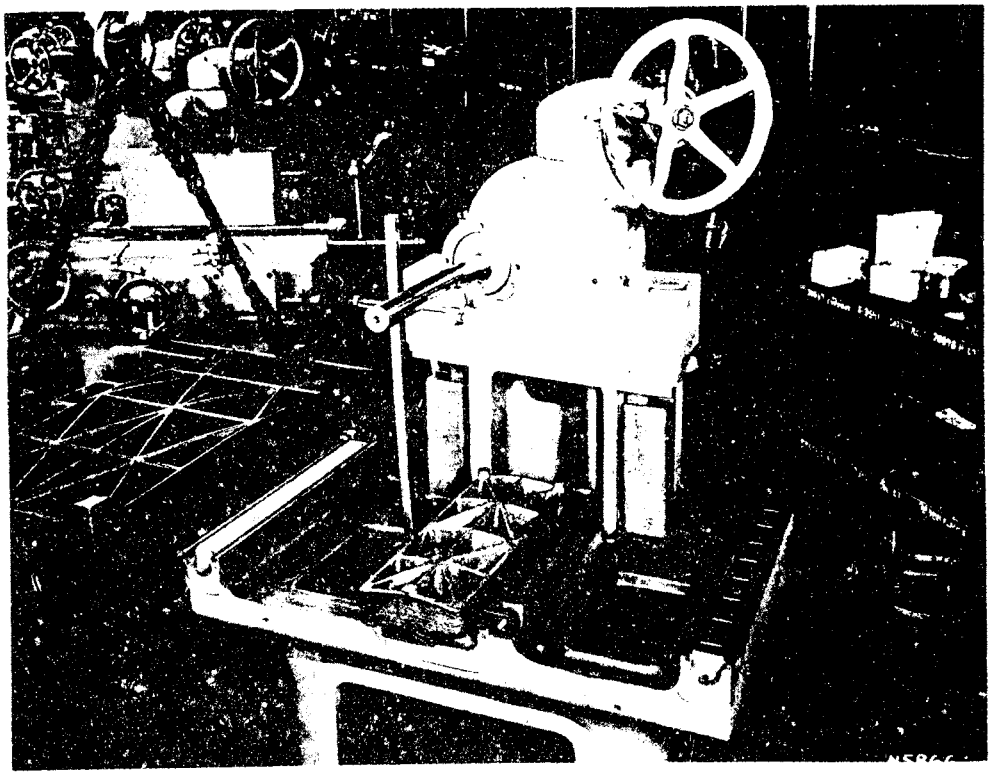

PLATE 68. Testing center guiding way of bed for parallelism with axis of spindle - horizontal plane. Tapered gib holds template against guiding way of bed during transverse movement of gage. (Courtesy - The Norton Company)

1. A PRECISION CYLINDER is placed in each V-way of the bed. Then a scraped plate having parallel surfaces is laid on the CYLINDERS, as shown in Fig. 30.10. (Incidentally, the special spotting plate mentioned in Sec. 30.10 could be used for our present purpose if the under-side is first scraped parallel to the top surface.) Next the beam of a TOOL MAKER'S SQUARE is set on the Plate in such a manner that the blade of the tool will be bucked against the upright way. If papers inserted between the blade and the bearing surface, at both top and bottom, hold equally when pulled, squareness is demonstrated. The test should be made against the right hand side and the left hand side of the front outer ways of the upright. A tolerance of .0004" in 6" is allowed.

2. Another test applicable for testing squareness in the vertical plane can be arranged, provided a special T-bar, made up to the form represented in Fig. 30.11, is available. Incidentally, making this piece of testing equipment involves a cylindrical grinding operation, not hand scraping. This T-bar is clamped to the front ways of the upright, as shown in Fig. 30.12. We prepare for the test by laying a PRECISION CYLINDER in each of the Vees of the bed. A PLATE having parallel surfaces is laid cross-wise on top of the cylinders. By placing a Surface Gage with attached DIAL INDICATOR on the PLATE, measurements can be made to the vertical diameter at both ends of the T-bar. A zero-zero reading indicates squareness in the vertical plane as specified

by OBJECTIVE NO. 1. A tolerance of .0004" in 6" is permissible.

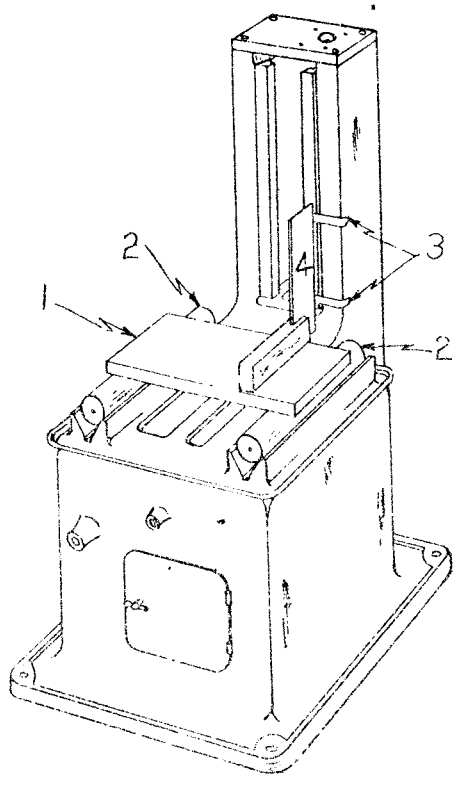

Fig. 30.10 Testing transverse V-ways of bed for squareness with upright ways in vertical plane. Tolerance maximum .0008" per foot.

(1) parallel sided scraped PLATE
(2) PRECISION-CYLINDERS
(3) papers
(4) TRY SQUARE

3. Another method of testing for squareness in the vertical plane is described as follows:

As a substitute for the T-shaped test bar mentioned above, a precision ground, cylindrical, straight test bar may be utilized as a target. After inserting it into the wheelhead housing, tests can be made to the vertical diameter of the bar with a DIAL INDICATOR attached to a stand positioned on the PLATE. The same tolerance is allowed, but the reading must be interpreted in relation to the error observed when the front slides of the housing were checked against the axis of the spindle. (Refer to OBJECTIVE NO. 1 in Sec. 30.18) In other words, the test

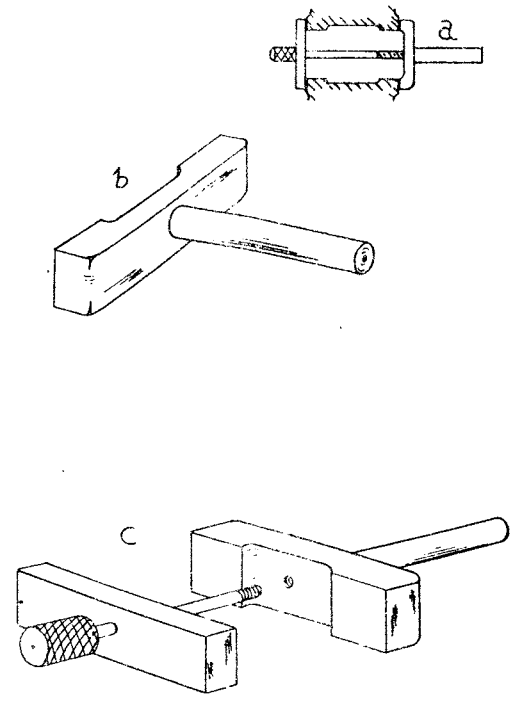

Fig. 30.11 View of special T-bar.

(a) clamped within upright ways (b) front view of T-bar (c) T-bar, clamping plate, clamp screw

executed with this set up is made to a check point which may itself be slightly misaligned with respect to the Datum Point. This possibility must, therefore, be taken into account when analyzing the instrument reading.

The convenience of this method lies in the fact that no time need be spent preparing special apparatus. The test bar utilized is the one prepared previously for use with the wheelhead housing. (See Sec. 30.16) It is entirely acceptable for the present situation.

In further tests for OBJECTIVE NO. 1 we check squareness of the transverse bed ways in the horizontal plane using one or the other of the following procedures, viz·

4. The set up illustrated in Fig. 30.13 is appropriate provided the V-way template mentioned earlier for spotting the ways of the bed was constructed as recommended. If available, it may now be used as a guide in the present situation to help check the squareness

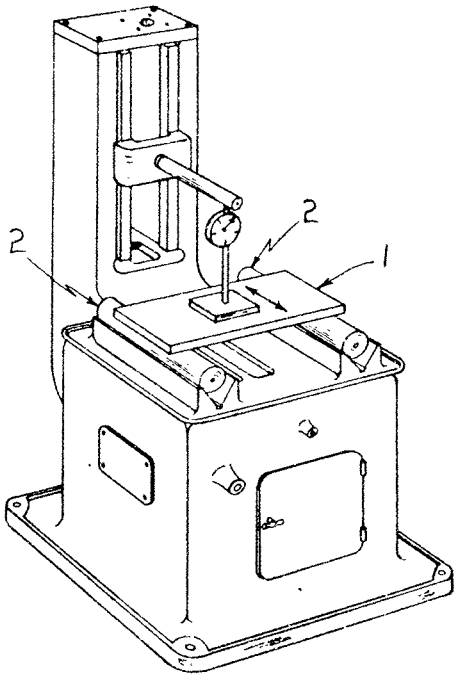

Fig. 30.12 Using DIAL INDICATOR and T-bar to test transverse ways of bed for squareness with upright ways (vertical plane). Tolerance maximum .0008" per foot.

(1) parallel sided scraped PLATE
(2) PRECISION CYLINDERS

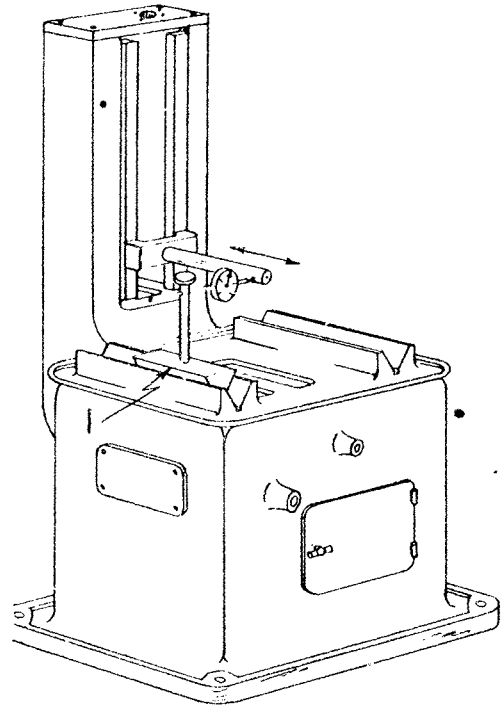

Fig. 30.13 Testing transverse ways of bed for squareness with ways of upright (horizontal plane), using special T-bar and DIAL INDICATOR. Tolerance maximum .0012" per foot.

(1) V-gage

of the Vees to the front pair of outer ways of the upright in the horizontal plane. Other apparatus necessary for the test includes either the T-shaped test bar or the straight cylindrical test bar, whichever is available. A DIAL INDICATOR attached in any convenient manner to the V-template is arranged so that it touches the horizontal diameter of the test bar as the template is moved along the V-way of the bed. A tolerance of .0006" in 6" is permissible. Each V-way of the bed is tested in turn.

5. An alternative method for testing the squareness of the transverse V-ways of the bed in the horizontal plane to the front outer ways of the upright is described as follows:

To make this test an apparatus similar to that shown in Fig. 16.19 must be devised. An acceptable jig would be one making a two point contact in one Vee and bridging across to make a one point contact in the other Vee. A DIAL INDICATOR is attached to the jig and adjusted so that its plunger touches the T-bar at the horizontal diameter.

Readings can be taken by moving the jig from end to end of the T-bar. A zero-zero reading signifies that the bed ways are square with the ways of the upright.

The readings so obtained in this particular test are valid only if the V-ways are parallel. Should the ways of the bed not be parallel, the jig will ride up or down in one of the Vees thereby registering falsely. As explained at the conclusion of this article (Sec. 30.23) there is sound reason to doubt that the transverse ways of the bed are truly aligned in vertical and horizontal planes. Consequently, even

the most conscientious performance is subject to future confirmation.

OBJECTIVE NO. 2 may be tested by arranging the following set up, viz: Two precision ground cylinders, such as described earlier, are laid in the Vees. A SURFACE PLATE is inverted and positioned on top of the two cylinders in the manner illustrated in Fig. 30.14. Papers are placed between the precision cylinders and the inverted SURFACE PLATE at all four corners. PARALLELISM as measured in the vertical direction is indicated if the papers hold equally firm at all positions when pulled. The tolerance allowed is .0004" in the overall length of the bed ways.

An equally satisfactory alternative method of measuring parallelism in the vertical direction consists of laying precision cylinders in the Vees of the bed, as explained above. A precision scraped PARALLEL is then spanned across the cylinders, say at the front of the machine. On top of the PARALLEL a PRECISION LEVEL is placed. The position of the bubble in the glass vial of the instrument may or may not register dead center. In any case, the location is noted whereupon the PARALLEL and LEVEL are transferred from front to rear. If there is no displacement of the bubble in the new position, the transverse ways of the bed are proved to be parallel measuring vertically.

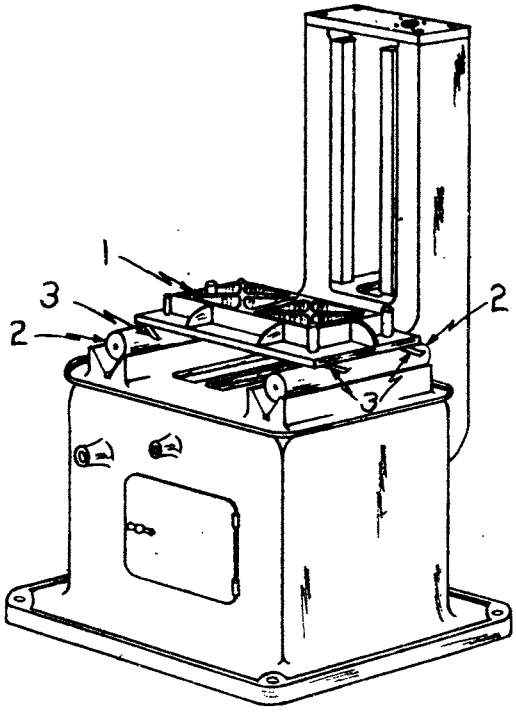

Fig. 30.14 Method of testing parallelism of transverse ways of bed, in vertical plane. Tolerance maximum .0004" in length of bed ways.

(1) SURFACE PLATE (2) PRECISION CYLINDERS (3) papers

To test for parallelism in the horizontal direction, lay a PRECISION CYLINDER in each Vee. Then using any convenient means, measure between them at the front and at the back of the bed. As an example, attach a rod of suitable length to one of the cylinders. Affix a DIAL INDICATOR to the holder and project it across to the cylinder resting in the other Vee. Using the swing-round method, as described in Sec. 16.4, bring the button of the instrument to bear approximately at the horizontal diameter of the cylinder. Note the maximum reading. Next remove the apparatus to the far end of the bed and take another reading. The difference between the two readings should not exceed a tolerance of .0004" in the length of bed.

Reviewing the material in Sec. 25.15 will be helpful in indicating more detailed methods for proving that the Vees are parallel in the horizontal plane.

Ordinarily, tests for OBJECTIVES NO. 1 and NO. 2 are made concurrently as the acceptance of one alignment is dependent upon the presumed accuracy of the other alignment.

Another important characteristic of the bed ways is straightness. Should this quality be lacking, the machine cannot grind parallel the opposite sides of a work piece. On Vees of short length, such as on a Plain Surface Grinder, this property is indicated by uniform markings overall when spotted with a STRAIGHT EDGE. Visual inspection is considered adequate, so special test apparatus is not required.

All OBJECTIVES must be fulfilled simultaneously.

CAUTION:

No matter how conscientiously the PROCEDURES for accomplishing OBJECTIVE NO. 1 are carried out,

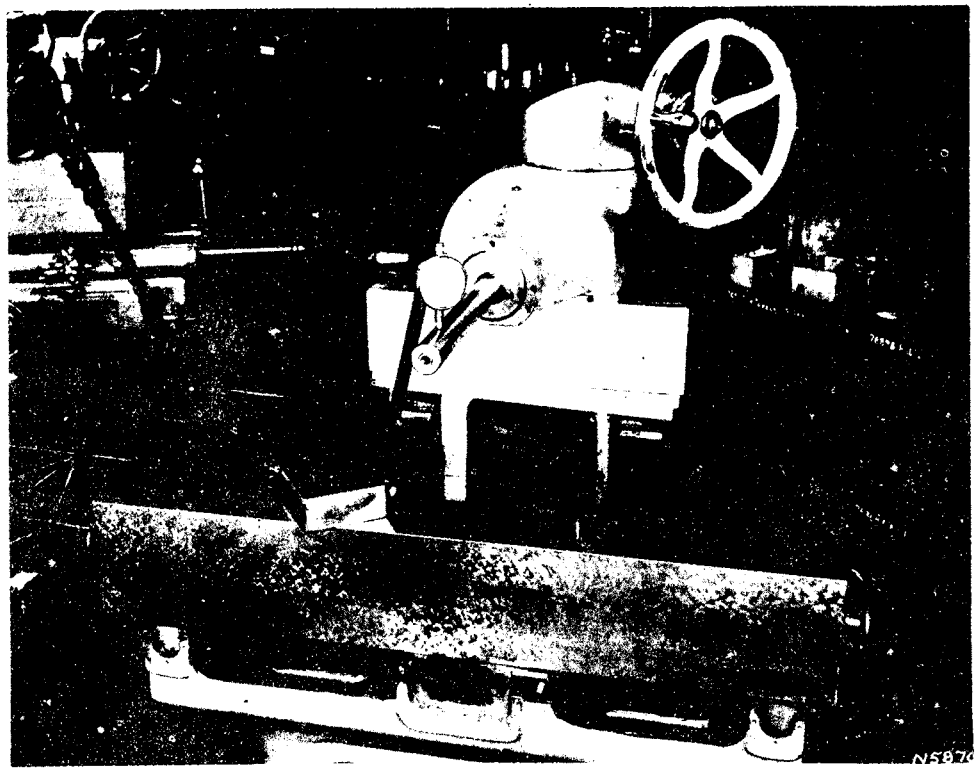

PLATE 69. Testing bed flat ways for parallelism with axis of spindle in vertical plane. Measurements are made with a dial indicator from a special scraped parallel to both ends of a test bar inserted in spindle. (Courtesy - The Norton Company)

CAUTION (cont'd.)

positive assurance in these operations is always open to question. The reason for this doubt is that the checks were made from each individual V-way to the test bar with apparatus utilizing a "line" contact. Truly accurate readings are possible only by testing from both V-ways as a unit with a template or machine member providing an "area" contact. Consequently, the alignment currently prevailing, having been checked by the less dependable method, should not be regarded as final but as tentative. Since maximum precision consistent with a reasonable expenditure of time and effort is desirable, a template, obviously, is required. In view of this, the slides of the carriage member which will be treated next are prepared as a template. Ultimately they will be utilized for this purpose. Then with the carriage available, conditions will be most suitable for accurate testing of the alignment of the bed ways to the Datum Point, or front outer ways of the upright, using either the T-bar or test bar as our check point. In short, this is as far as we carry at present the operation on the ways of the bed.

Sec. 30.24
The Carriage.

The carriage member has two sets of bearings. Underneath are the carriage slides which are fitted to the ways of the bed. These provide transverse movement to the member. On top are the carriage ways which are aligned to the upright. It is these carriage ways which guide the work-table in longitudinal movement.

Sec. 30.25
OBJECTIVE: The Slides of the Carriage member.

1. To be fitted to the ways of the bed with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

Though only one OBJECTIVE is specified, actually, treatment of the slides of the carriage is designed to effect an additional result, namely; to provide a template with which precise tests can be made to prove the accuracy of the alignment of the bed ways to the front outer ways of the upright.

The slides of the carriage, shown in Fig. 30.15, are inverted Vees. To spot them we employ the ways of the bed as a template. (Marking compound may be spread on either set of bearings.) After each spotting cycle the slides of the carriage are scraped in accordance with the indicated markings.

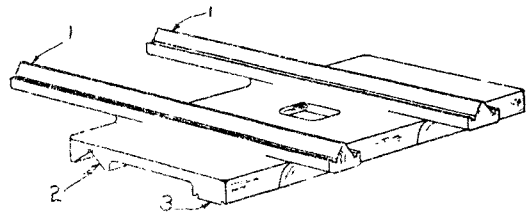

Fig. 30.15 Carriage member inverted to show underside.

(1) Inverted Vee slide (2) V-way (3) flat way

Since straightness in the inverted V-slides makes for good fit, this condition should be checked frequently with a STRAIGHT EDGE.

When a final spotting reveals a uniform distribution and coloration of bearing spots, adequate in number, the slides of the carriage are judged well fitted to the ways of the bed.

While pursuing the above course, the scraper should not overlook the fact that

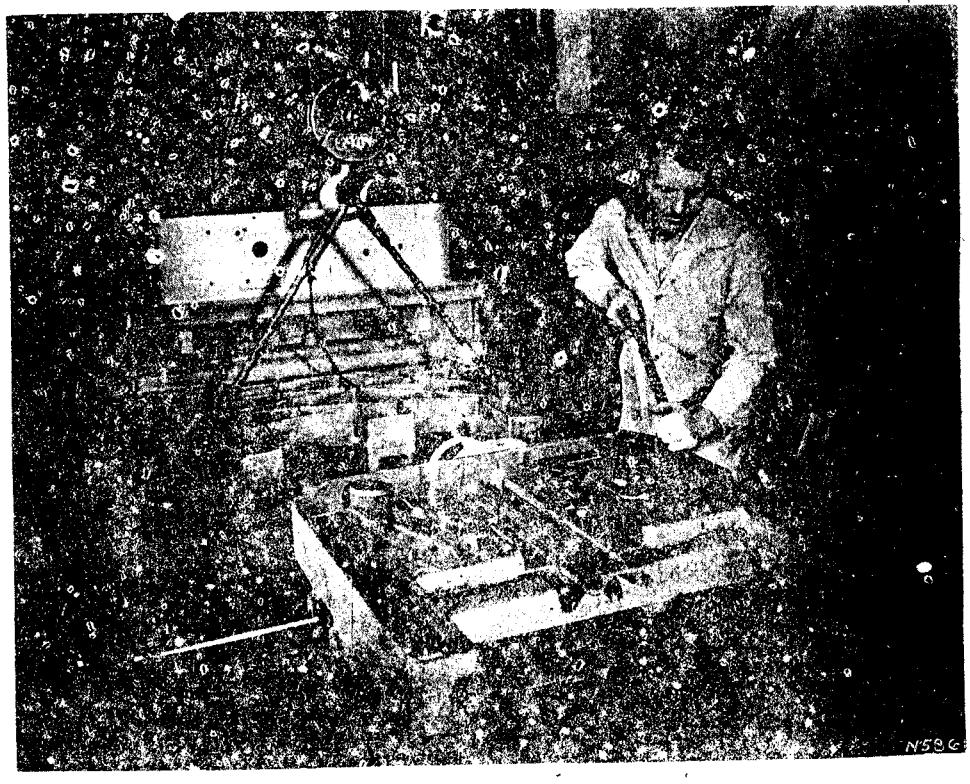

PLATE 70. Scraping operation on the slides of carriage of surface grinder. Note the special precision template suspended from crane hook used for spotting these bearings. Notice in the background another carriage suspended and positioned to show the top surface. (Courtesy - The Norton Company)

the upper bearing surfaces of this member, to wit, the carriage ways, must be aligned next and that the present treatment of the carriage slides figures heavily in facilitating or retarding that job.

Remember that ultimately the carriage ways must be aligned square with the carriage slides. Hence, merely scraping the slides for a "fit" with the bed ways, without regard for preserving original relationships, may result in throwing the carriage ways excessively out of alignment. To repair the damage thus wrought an unnecessarily large quantity of metal must later be removed from the ways.

A far better practice to follow is to make occasional tests on the carriage ways to determine whether they are being kept reasonably square with the carriage slides as these bearing surfaces are being fitted. The procedure to employ is outlined in the following Sec. 30.26 as OBJECTIVE NO. 3. If due regard is given to this requirement, the carriage ways will not be found excessively misaligned when the carriage alides are deemed fitted to the bed ways.

As we have pointed out in numerous instances before, the scraper must never become so engrossed in current operations that their possible effect on other surfaces and members is lost sight of.

One measure that makes for efficient treatment of all members is application to each surface, as one comes to it, of the maxim "scrape straight down". If this is done successfully, there will result a bearing parallel to the original factory-new surface and this will be accomplished without excessive misalignment of other surfaces yet to be scraped. The interested reader is advised to refer to Sec. 23.21 for additional details

At this juncture we should again test the V-ways of the Bed for alignment with respect to the front outer ways of the

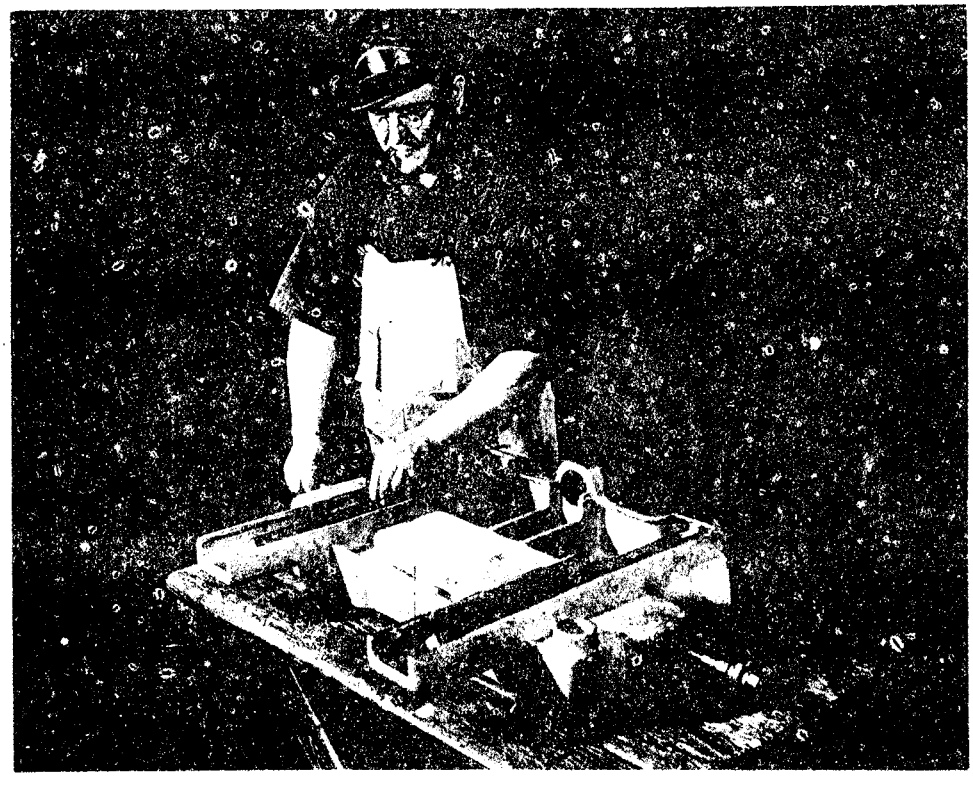

PLATE 71. Prussian blue being applied to the lower bearing surfaces (inverted V slides) of the carriage. A film of red lead applied to the V-ways of the bed will provide effective contrast between the two mediums when the surfaces are brought together and checked for bearing quality and fit. (Courtesy - Galimeyer & Livingston Co.)

upright. In order to insure maximum precision, this should be done using the carriage as a template.

To digress for a moment, the reader will recall that Sec. 30.23 described a number of procedures useful in testing the abovementioned alignment and concluded with a CAUTION warning of the limitations of those methods. By using the carriage member as a template this question can now be determined with close accuracy. If the procedures referred to were conscientiously applied, the existing alignment will be found within the allowed tolerance or near to it. Thus any inaccuracy noted at this time can be quickly corrected.

By referring again to Sec. 30.23 the reader can refresh his memory in regards to the OBJECTIVES specified for the bed ways.

The set up to prove that the axes of Vees are square with front pair of outer ways of upright calls for a T-shaped test bar secured to the front outer ways of the upright. A DIAL INDICATOR is fastened to the carriage member in any convenient manner. The plunger button of the instrument is then positioned in turn at the vertical and horizontal diameters of the T-bar.

Tests are made successively on both the vertical and horizontal diameters of the test bar as the carriage is moved back and forth. The tolerance allowed is the same as given before.

If the tolerance is exceeded, the bed ways must be rescraped to conform to the accuracy standard specified. Obviously, any alteration to the transverse bed ways will necessitate additional scraping on the slides of the carriage in order to refit them to the mateing ways. Possibly these corrections must be made back and forth a number of times before the alignment of the bed ways is deemed acceptable and the fit of the carriage slides satisfactory.

After correctly fitting the table slides, experienced scrapers will not be satisfied until a final alignment test of the bed ways proves the accuracy of the scraping job. Conscientious efforts to achieve maximum precision on these important bearing surfaces are amply rewarded later in the form of accurate grinding by the machine.

Sec. 30.26

OBJECTIVES: The ways of the carriage.

1. To be parallel.
2. To be straight and level.
3. Axis of V-way to be square with the axis of spindle in the horizontal plane.
4. To haye a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

The ways of the carriage located on top of the member consist of one V-way and one flat way, as shown in Fig. 30.16. In treating these bearings, convenience is served by performing the spotting and scraping operations with the carriage mounted on the bed. The carriage overhangs the bed sufficiently so that grit and chips will not fall into the Vees of the lower member. Another reason for working with the carriage mounted is that alignment tests must be made frequently and this position facilitates rapid set ups.

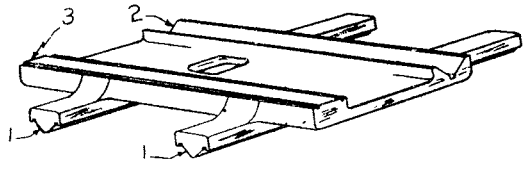

Fig. 30.16 View of top side of carriage member.
(1) Inverted Vee slide (2) Vee way (3) flat way

Spotting of the carriage ways is performed by means of a STRAIGHT EDGE. After a few cycles of alternate spotting and scraping, the surfaces are usually smooth enough to begin checking alignments.

To test for OBJECTIVE NO. 1 place a precision CYLINDER in the Vee, say on the right hand side of the machine. Wring a number of PRECISION GAGE BLOCKS together and place them on the flat way. Bridge between the BLOCKS and CYLINDER with a SCRAPED PARALLEL. Lay a PRECISION LEVEL on top. GAGE BLOCKS are added till the bubble in the glass vial is centered. Then the apparatus is moved intact to the other end of the member. The bubble must

center in the new location also to prove that the V-way and flat way are parallel. (This test is discussed in somewhat greater detail in Sec. 25.14)

The straightness of both ways will be verified by uniform coloration of the markings after spotting. A further check of this characteristic can be made by applying the Pivot Test on the flat way. (See Sec. 22.3) Levelness in each way, also specified in OBJECTIVE NO. 2, is proved by standard methods.

The reason for placing so much emphasis on having the ways straight is that lacking this characteristic the surface grinding machine cannot grind parallel the opposite sides of a work piece.

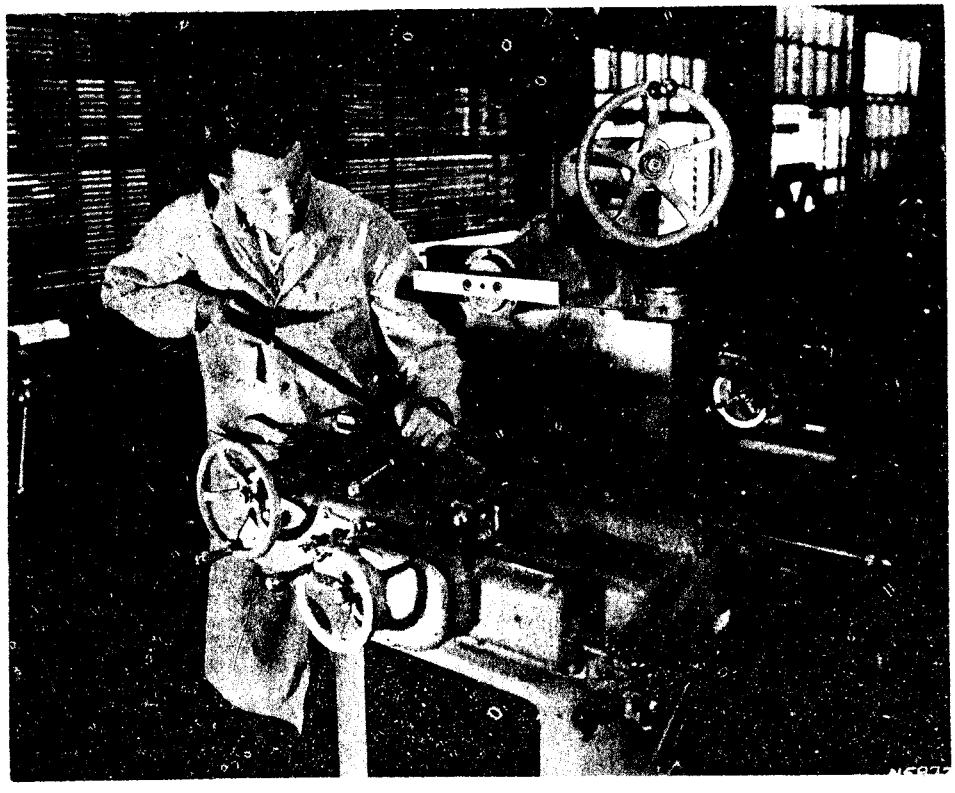

PLATE 72. Scraping the Vee way and flat way of the carriage of surface grinder. Note the dummy spindle and attached Tee bar inserted in the wheel head housing. (Courtesy - The Norton Company)

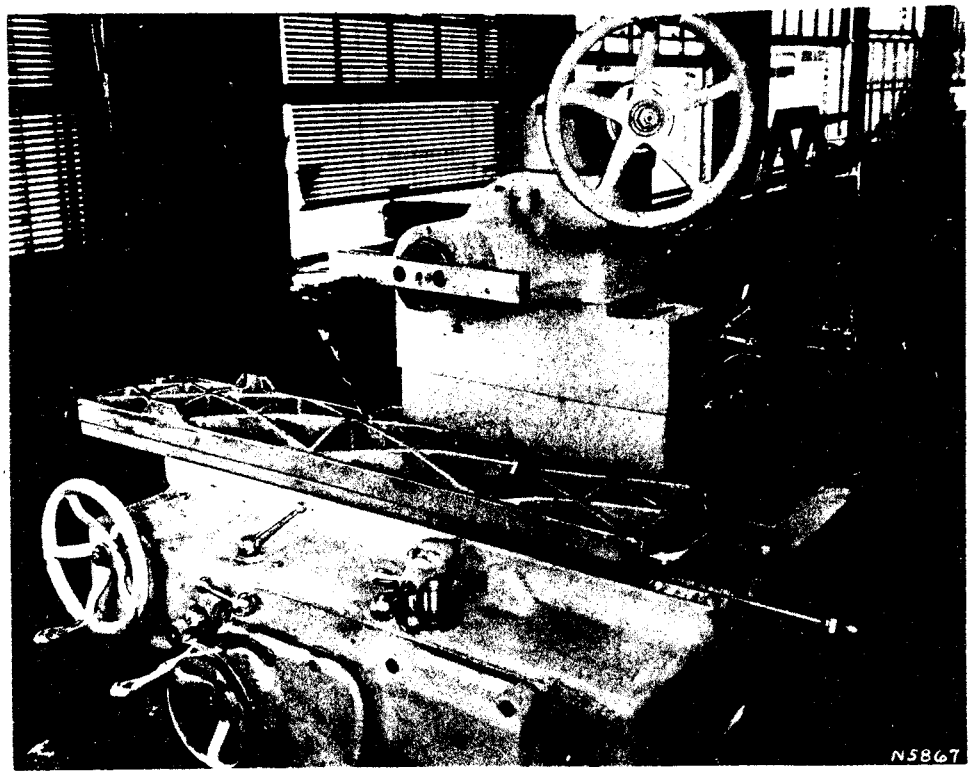

PLATE 73. Testing Vee and flat way of carriage square with axis of spindle. Dial indicator readings are taken at both ends of the T-bar as the spotting template is slid along the carriage ways. (Courtesy - The Norton Company)

For checking OBJECTIVE NO. 3 a PRECISION CYLINDER is placed in the V-way. A long rod or arm holding a DIAL INDICATOR is fastened to the wheel spindle. The button of the instrument is positioned on the CYLINDER at the horizontal diameter, whereupon the fact of the DIAL is zeroed. Next the cylinder is transferred to the opposite end of the Vee. Then the rod holding the instrument is swung around so that the plunger button again touches the cylinder at the horizontal diameter. The tolerance allowed is .0002" per foot.

The aforementioned alignment tests should be conducted consecutively following cycles of spotting and scraping. All four OBJECTIVES must be completed simultaneously.

PLATE 74. Method of proving the ways of the carriage are square with the axis of the spindle. Using the swing-over method, a dial indicator fastened to the spindle must check zero-zero at both ends of the test bar laid in the carriage V-way. (Courtesy - Gallmeyer & Livingston Co.)

Sec. 30.27
The Work-Table.

This member, represented in Fig. 30.17, bearing on an inverted V-slide and flat slide moves longitudinally guided by the ways of the carriage. The top surface of the work-table supports the work piece either by clamping to the T-slots provided or by means of a magnetic chuck.

Sec. 30.28
OBJECTIVES: The Slides of the Work-Table.

1. T-slots to be parallel with table movement.
2. To be fitted to the ways of the carriage with a surface quality of 10 - 15 bearing spots per square inch.

PROCEDURE:

Before tackling the work-table the operator should ascertain what class of work the machine is to perform. If the machine is to do all grinding with the work pieces clamped to the table top or mounted on a magnetic chuck, OBJECTIVE NO. 1 may be disregarded because the T-slots would only be used for holding purposes. On the other hand, if the T-slots are to be employed to align special fixtures in order to conduct diverse grinding operations, OBJECTIVE NO. 1 must be fulfilled. To avoid unnecessary work, the experienced operator decides at the very outset whether or not aligning the T-slot is essential.

Assuming that the more exacting requirement is called for and that the alignment must be satisfied, the first step is to inspect the condition of the

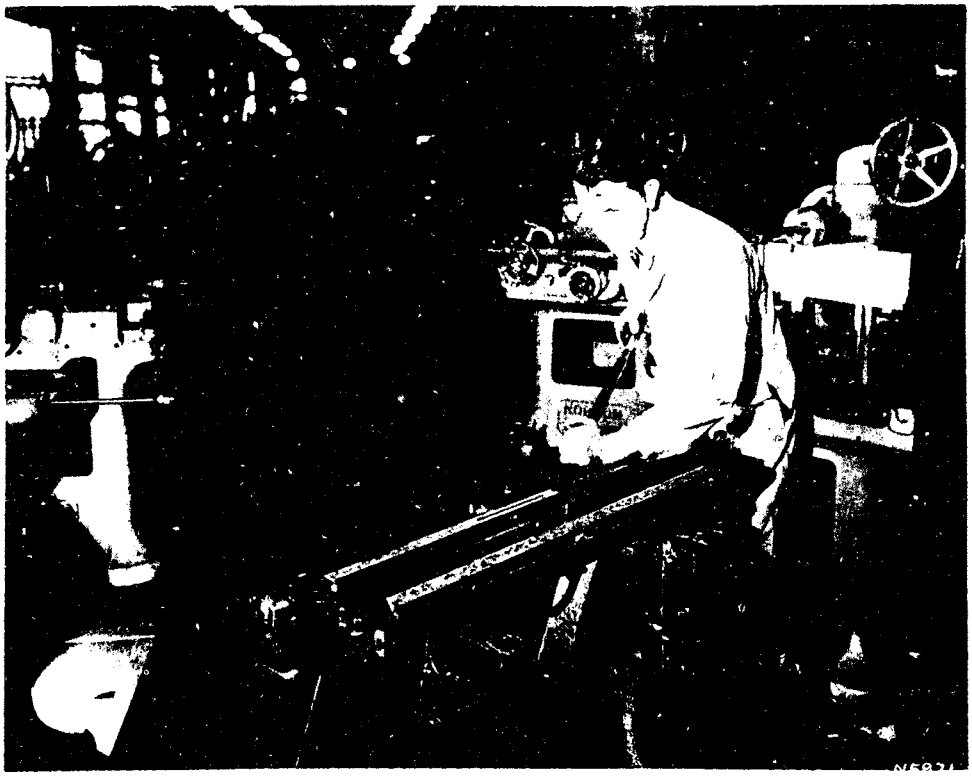

PLATE 75. Scraping the flat slide and inverted V-slide of the work table of surface grinder. These surfaces will be fitted to the already scrape-finished ways of the carriage. (Courtesy - The Norton Company)

throats of the T-slots. They should be checked for burrs and for roughened worn areas. The burrs can be removed quite easily by filing or scraping. Obviously, if serious abrasion is apparent it will be necessary to grind the throats.

When it is seen that the T-slots require grinding, which always is done in place, time can be saved if the present alignment of the T-slots to table movement is disregarded. In such a case, the scraping is designed strictly to "fit" the slides to the carriage ways. Of course, to reduce the depth of grind and consequent excessive widening of the slots, the experienced scraper will endeavor to "throw" the T-slots by judiciously scraping the slides underneath.

On the other hand, if the T-slots are not in need of grinding for the purpose of smoothing them, they should not be ground to effect the required alignment. Grinding widens the T-slots which necessitates the replacement of the tongues of all grinding fixtures.

Before either scraping the slides of the work-table or grinding the T-slots on top, the present accuracy of the alignment of center T-slot with respect to table movement should be ascertained. For example, a DIAL INDICATOR can be attached to the wheel guard and so adjusted that the plunger button touches one side of the throat of the center T-slot.

A reading is obtained as the tabls is traversed longitudinally.. The tolerance allowed amounts to .0002" per foot of table length. Both sides of the throat of the center T-slot are tested in like manner.

Having information now as to the degree of misalignment, corrective treatment of the table slides can be started. When treating these slides, it is customary to use the ways of the carriage as a spotting template. On alternate spotting

cycles, a STRAIGHT EDGE can be applied in order to expedite the work.

The misalignment can be eliminated by scraping the inverted V-slide of the table so as to "throw" the T-slot in the proper direction and by the correct amount.

After every few cycles of scraping, the alignment test for OBJECTIVE NO. 1 should be repeated to determine progress.

Since the abovementioned test is adequate for our purposes, the mention of auxiliary tests would be superfluous. At the risk of being tedious, it might be well, though, to point out that the rack (3) Fig. 30.17 fastened underneath the table can be utilized as a check point because when manufactured it was aligned parallel with the T-slots. By utilizing this check point in conjunction with a suitable indicating jig, scraping progress on the table slides may be quickly and conveniently ascertained.

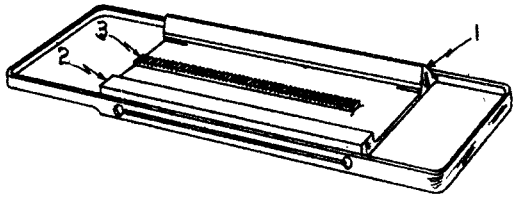

Fig. 30.17 Underside of work-table of plain surface grinding machine.

(1) inverted V-slide (2) flat slide (3) rack

Straightness of the table slides is essential to accurate surface grinding. Although not mentioned specifically in the OBJECTIVES, it is understood to be a factor in fitting these bearings to the ways of the carriage.

Straightness should be tested by every known method leaving nothing to chance. One procedure to employ is spotting. In this case, the spotting is performed with the ways of the carriage which, being about as long as the table, produce colored markings deemed reliable. Additionally, the STRAIGHT EDGE should be applied periodically to the table slides to check this condition. Since maximum precision is desired, the operator should manipulate the testing tools with all the skill possessed.

Sec. 30.29

OBJECTIVES: The Top surface of the work-table.

1. To be parallel with the table slides in the longitudinal direction.
2. To be parallel with the slides of the carriage in the transverse direction.
3. T-slots of table to be parallel with table movement.

PROCEDURE:

With the slides of the table well fitted to the ways of the carriage, the next step is to align the top surface of the table. All gearing, feed screws, and auxiliary equipment must be assembled and inserted preparatory to mounting the table.

OBJECTIVES NO. 1 and NO. 2 are most accurately attained by grinding the table in place on the machine. Grinding of the table top is a precision job requiring strict compliance with the rules of surface grinding with special emphasis on the selection of the proper wheel and depth of grind.

The tolerance allowed in the longitudinal direction is .0002" per foot of table length. The tolerance permitted in the transverse direction is .0004" in the table width. For testing methods refer to Static Alignment Tests No. 3 and No. 4, Sec. 30.34 and Sec. 30.35, respectively.

To supplement the above we should apply the widely useful Three Paper Test (Sec. 22.4) to determine the flatness of the finish-ground table top. Preparation for this test consists of evenly spacing three strips of paper in a fairly straight row across the table top. On top of these papers is set a hardened steel STRAIGHT EDGE. In succession, the papers are pulled by finger. Uniformity of pull denotes flatness or absence of curvature. In order to test all portions of the surface, the papers are shifted to different positions and the procedure repeated.

CAUTION:

If the Three Paper Test indicates that the table top is not flat after grinding there are several incidental possibilities to be considered. One reason may be improper grinding techniques. The reader is urged to consult appropriate text books for up-to-date information

CAUTION (cont'd.)

on grinding practice. Another reason for the failure may be attributed to warping of the carriage member. It is well to investigate whether a bolted part, a splash guard for example, may not be the origin of the trouble. The strain imposed by such an auxiliary part may appreciably affect the sensitive alignments of precision surface grinding machines.

As explained previously in Sec. 30.28, aligning the T-slots to table movement may be accomplished in either of two ways. It can be done either by scraping underneath slides of the table so as to "throw" the T-slot in the proper direction, or by grinding the T-slots in place.

In the sequence being followed the slides of the table have been scrape-fitted and we may, therefore, assume that the alignment required by OBJECTIVE NO. 3 has been fulfilled. However, in case the fitting was done without regard for this requirement, the alignment specified in OBJECTIVE NO. 3 can now be attained only by grinding the T-slots in place. Of course, the throats of the T-slots must be ground parallel their entire length.

Before undertaking this operation determine the amount of misalignment by repeating the test described in Sec. 30.28. A tolerance of .0002" per foot is allowable (with the T-slots finish-ground).

NOTE:

Any grinding of the throats of the T-slots will necessitate altering the tongues of all fixtures.

Sec. 30.30
OBJECTIVE: The Magnetic Chuck of the surface grinder.

1. To be parallel with the table top.

PROCEDURE:

Strictly speaking, the magnetic chuck is not a part of the plain surface grinder, but inasmuch as it is a commonly used auxiliary and inasmuch as the reconditioning procedure can be described briefly, it will be included in the sequence, as follows:

The magnetic chuck is inverted on the table top and the base ground. Then the member is placed in operation on the table top and clamped lightly in place. Next utilizing a DIAL INDICATOR, the front of the chuck is aligned parallel with the table travel, whereupon the member is tightly clamped. The working surface of the magnetic chuck is now ground in place. This operation is performed in the "on" position, that is, with the chuck magnetized.

The accuracy of the grind will be tested by grinding sample work pieces to be described later.

CAUTION:

As sometimes happens, a faulty chuck may be encountered in which case its working surface cannot be ground flat. If all other possible sources of trouble have been investigated and eliminated, it is advisable to substitute another magnetic chuck and repeat the grinding process.

Sec. 30.31
Working Test.

After the magnetic chuck is finish-ground, sample pieces should be ground to determine the working accuracy of the machine. To this end small blocks of hardened tool steel are spaced across the chuck to cover a representative portion of its surface. They are ground on one side, inverted and shifted to a corresponding position on the opposite side of the chuck and ground again. This transfer will expose the blocks to the maximum error present. After grinding both sides, the test pieces are measured for parallelism.

The average plain surface grinder used in the tool room should be able to size these work pieces as to thickness and parallelism on a rough grind within 0.0003" and on a finish grind within 0.0001" over a working area of approximately one (1) square foot.

STATIC ALIGNMENT TESTS

If the results of the Working Test just concluded fall short of the established standards of Working accuracy, the origin

of the trouble may be traced to one or more of the following factors, viz:

1. That assembly of feed screws, gearing etc. was faulty leading to a strain being imposed on the machine.
2. That the rules of good grinding practice were violated.
3. That an alignment previously thought realized was in truth not accomplished.

It is impossible to specify precisely were a possible error suggested in point #1 above might lie. Therefore, all phases of assembly should be very carefully re-examined to discover the source of trouble.

The accuracy and finish of grinding operations depend on the material being ground, the diameter, width and character of the wheel, speed of wheel and work, depth of cut, rate of traverse, suitability of the coolant, as much as on the condition and rigidity of the machine. These factors inferred in point #2 above are beyond the scope of this book.

As for point #3 above, a series of related static alignment tests will determine the source of the working inaccuracy when due to a misalignment in the several bearing surfaces of the members previously treated.

These tests are enumerated below in the sequence most interpretative. It will be noted that the tests are interdependent and that they are arranged in an order whereby the established accuracy of a preceding test provides a sound basis for a succeeding test. By this procedure it is possible to demonstrate the prime cause for a particular misalignment.

If the permissible tolerances of the entire series of tests are not exceeded, the working accuracy of the machine is assured.

Sec. 30.32
STATIC ALIGNMENT TEST NO. 1

Levelness of Table Top.

PROCEDURE:

Fig. 30.18 represents the test for levelness. The instrument is set successively in two directions on the working surface of table or magnetic chuck. If the tolerance is exceeded, the base of the casting should be shimmed to correct the error.

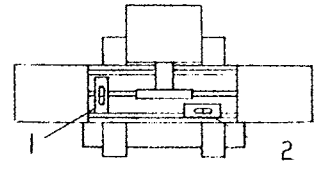

Fig. 30.18 Table level in longitudinal and transverse directions. Tolerance in -

(1) transverse direction (±) 0.0002" per foot. (No wind permitted)
(2) longitudinal direction 0.0002" per foot.

An unlevel condition may occur if the machine is set up at a different location from where it was scraped in. The leveling operation should be done precisely to prevent inducing a "wind" in the bearing surfaces of the bed or upright. A "wind" is a common cause of inaccurate grinding of piece parts.

Sec. 30.33
STATIC ALIGNMENT TEST NO. 2

Accuracy of wheel spindle and centering sleeve.

PROCEDURE:

Fig. 30.19 is practically self explanatory. The tapered portion of the wheel spindle is tested for true running with the set up shown at (a).

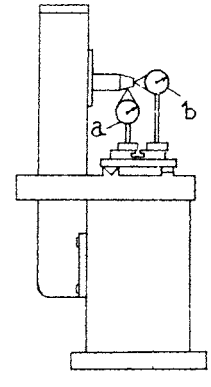

Fig. 30.19 Testing accuracy of wheel spindle.

(a) for concentricity of taper section Tolerance - 0.0004"
(b) for cam action Tolerance - 0.0004"

The wheel centering sleeve having been placed on the spindle is tested for cylindricity by positioning the plunger of the DIAL INDICATOR on the circumference.

The set up at (b) will test the wheel spindle for cam action.

If the tolerance for this accuracy standard is exceeded, the measures discussed in Sec. 30.4 must be adopted.

Incidentally, the condition of the grinding wheel spindle and its bearings determines, in large measure, the quality of the surface finish on the work piece.

Sec. 30.34
STATIC ALIGNMENT TEST NO. 3

Rise and Fall of Table in Longitudinal Movement.

PROCEDURE:

Fig. 30.20 represents the method of checking the movement of the table in longitudinal direction.

If the tolerance is exceeded, a probable cause of the error would be non-parallelism in the ways of the carriage or else poorly fitted table slides. Either condition would induce a "wind" in the table top as it is ground in place.

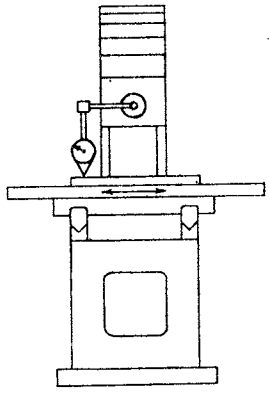

Fig. 30.20 Rise and fall of table in longitudinal direction. Tolerance maximum 0.0002" per foot of table length.

The first step in the process of finding the source of the inaccuracy is to remove the table and test the carriage ways for parallelism as suggested in Sec. 30.26. Should the test reveal that this characteristic is lacking, the carriage ways must be rescraped. Following this, the table slides must be re-fitted to the ways. Finally, the table top is re-ground and again tested.

CAUTION:

It is good practice to defer scraping until other tests pertinent to the table slides and carriage ways are also made. Correction can then be performed on a comprehensive basis. Pertinent tests include No's 5, 6, 8, and 9.

CAUTION:

To assure reliable readings do not position the button of the DIAL INDICATOR directly underneath the axis of the wheel spindle.

Sec. 30.35
STATIC ALIGNMENT TEST NO. 4

Top Surface of work-table parallel with transverse movement.

PROCEDURE:

The test of the top of table measured in its transverse movement is shown in Fig. 30.21.

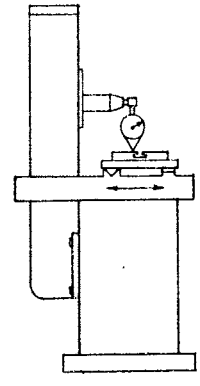

Fig. 30.21 Rise and fall of table in transverse direction. Maximum tolerance 0.0004" on total width of table.

Exceeding the tolerance may be due to non-parallelism of the transverse ways of the bed or improper fitting of the carriage slides. Either condition could introduce a "wind" in the table top

during grinding in-place. Work pieces ground on such a machine would be similarly affected.

As a first step in tracing the fault to its source, the carriage-table assembly is removed. Then the transverse ways of the bed should be tested for parallelism as described in Sec. 30.23. If the tolerance is exceeded, the bed ways must be rescraped and retested successively until accepted.

As a sequel to this, the slides of the carriage must be refitted and the alignment of the bed ways retested, as discussed in Sec. 30.25. Finally, the top of the work-table is reground in position and the static alignment test repeated.

CAUTION:

Defer scraping until all tests applicable to the bed ways and carriage slides have been made. Pertinent tests include No's 5, 8, and 9.

CAUTION:

To assure reliable readings, do not position the button of the DIAL INDICATOR directly underneath the grinding wheel.

Sec. 30.36
STATIC ALIGNMENT TEST NO. 5

Table movement parallel with ways of upright.

PROCEDURE:

Fig. 30.22 represents the test of table movement with respect to ways of upright.

If the tolerance is exceeded, the origin of the error lies in the misalignment of the axis of the carriage V-way with relation to the ways of upright. This alignment should be rechecked as discussed in Sec. 30.26. In this procedure the spindle is used as a Check Point.

The guiding way of the carriage must be made parallel with the ways of the upright in the horizontal plane. When parallelism is realized, the table slides must be refitted and the table top reground.

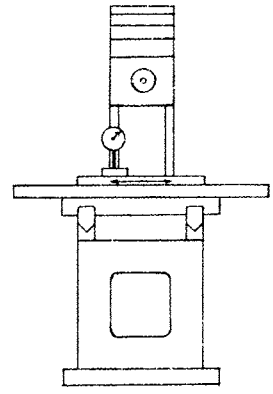

Fig. 30.22 Table movement parallel with ways of upright. Maximum tolerance 0.0002" per foot.

Sec. 30.37
STATIC ALIGNMENT TEST NO. 6

T-slots parallel with table movement.

PROCEDURE:

The alignment test diagrammed in Fig. 30.23 shows the tolerance permitted for alignment between the T-slots on table top and the table movement in the longitudinal direction.

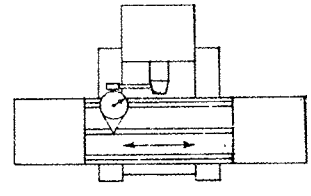

Fig. 30.23 T-slots parallel with table movement. Maximum tolerance 0.0002" per foot.

This alignment is governed solely by the relationship between the guided slide of the table and the T-slots on top.

There can be no misalignment of the T-slots if they were ground in-place after the table slides were fitted.

If grinding was not utilized to widen the slots or smooth them, then the guided slide must be rescraped to effect the proper alignment of T-slots to table movement. This means that both the inverted V-slide and flat slide of table must be refitted to carriage ways.

Sec. 30.38
STATIC ALIGNMENT TEST NO. 7

Wheel spindle square with T-slots.

PROCEDURE:

Represented in Fig. 30.24 is a test to prove whether axis of the wheel spindle is square with the T-slot. If the tolerance is exceeded, the right hand slides of the wheelhead housing were not scraped parallel with the axis of the spindle. This must be corrected as described in Sec. 30.16.

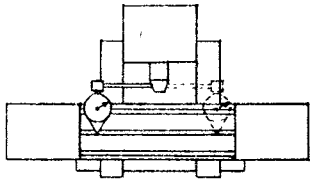

Fig. 30.24 Wheel spindle square with T-slots. Maximum tolerance 0.0008" per foot.

Should the clearance between the slides of the wheelhead housing and the ways of the upright become excessive as a result of the removal of metal, new and thicker straps must be attached to the left hand slides of the housing to take up the slack.

It is quite likely that the front slides of the wheelhead housing must be refitted and the bracket bearings of the same member rescraped parallel and given the proper clearance to match the new situation.

CAUTION:

Defer scraping until all tests pertaining to alignment of the wheelhead housing, such as TEST NO. 10, have been made.

Sec. 30.39
STATIC ALIGNMENT TEST NO. 8

T-slots square with transverse movement of table.

PROCEDURE:

The test shown in Fig. 30.25 is designed to show the existent alignment between the T-slots and the transverse ways of the bed.

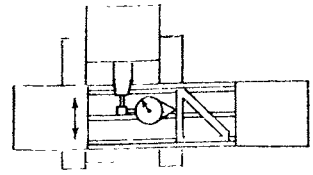

Fig. 30.25 T-slots square with transverse movement of table. Maximum tolerance 0.0015" per foot.

If the tolerance is exceeded the bed ways are known to be misaligned with respect to the Datum Point since previous tests, if within the allowed tolerance, have proven the T-slots correctly aligned.

The bed ways must, therefore, be rescraped to bring about accurate alignment. Necessarily this requires re-fitting the carriage slides. As a result of this operation, the ways of the carriage will now be misaligned, and they also must be rescraped to return them to their original alignment as specified in Test No. 5.

Following this the table slides must be refitted and the table top re-ground. From the foregoing it is apparent that much work must be done over by reason of the failure of the scraping operator to attain the alignments on a particular member the first time that member was dealt with.

Sec. 30.40
STATIC ALIGNMENT TEST NO. 9

Vertical adjustment of spindle square with table top.

PROCEDURE:

As Fig. 30.26 indicates, the bed ways are aligned square with the upright ways. If the tolerance is exceeded, the bed ways must be re-scraped to correct the misalignment. The work entailed to correct the error will affect other members of the machine also, thereby necessitating one or more of the following operations, viz: refitting carriage slides, realigning the carriage ways, refitting of table slides, regrinding top of table, possible re-leveling of machine and repeating all the static alignment tests thus far made.

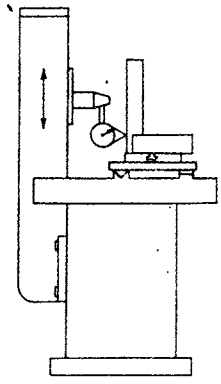

Fig. 30.26 Vertical adjustment of spindle square with table top. Max. tolerance 0.0025" per foot.

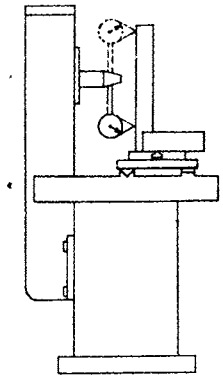

Fig. 30.27 Axis of spindle parallel with table top. Maximum tolerance 0.0008" per foot.

Sec. 30.41
STATIC ALIGNMENT TEST NO. 10

Axis of spindle parallel with table top.

PROCEDURE:

Represented in Fig. 30.27 is the test to prove that the axis of the spindle is square with the Datum Point i.e. upright ways in the vertical plane.

If the tolerance is exceeded then the front slides of the wheelhead housing must be rescraped to correct this misalignment. The method is described in Sec. 30.18.

Additionally, the bracket bearings of wheelhead housing must again be rescraped to provide:

1. The required parallelism with the front slides of this member.
2. The proper clearance for the member between front and rear ways of the upright.

GLOSSARY OF TERMS

It is not the purpose of this glossary merely to add to the large number of dictionaries extant. That would be both superfluous and vain. The following list can be justified because convenience is served by compiling for easy reference frequently used words of general application and others having a special connotation to the scraping art.

abrasion: A wearing away, as on a bearing surface

accuracy: Truth; precision

acute angle: Said of male or female dovetails; less than 90°

adjust: To suitably arrange tools, instruments or machine parts

affix: To attach a tool or instrument, as for test purposes.

ageing: Reducing stresses and strains in metal by natural processes; seasoning.

align: To bring two axes, or two surfaces, or a surface and an axis into proper relationship, as concentric, square or parallel.

alternate: To employ two or more tools in succession though not necessarily in an inflexible sequence

anneal: Softening metal by heating to the desired temperature and cooling slowly.

apprentice: A novice, a beginner, especially one learning a trade.

apron: A machine part, as a lathe apron

area contact: A condition denoted by maximum bearing and full seating; opposed to line contact which is a threadlike bearing of one surface on another.

axially: In the direction of an axis.

axial slip: See cam action

axis: A straight line passing through a body about which it revolves, as a spindle axis

backing out: Withdrawal from contact, said of a tool.

back lash: The measurable distance a meshed gear moves before connecting the load.

bearing: The slides or ways: a surface condition which may be characterized as good or poor.

bearing plane: The effective contact surface of a sliding bearing

bearing spots: Minute surface projections all in one plane

bed: The main horizontal casting which supports the auxiliary components, as the bed of a grinder, the bed of a lathe. (When the main casting is positioned vertically, it is more aptly called a column.)

bisect: To divide into two equal parts, as an angle

bite: To incise or cut, said of the cutting edge of a scraper blade

blade: The cutting part of a scraper tool

blemish: A flaw affecting appearance

blow hole: A cavity in a metal piece formed by gases when casting; a defect

boss: A raised part of a casting to which a shaft is affixed.

bottom: To touch the surfaces of a groove with a spotting tool.

burr: A roughness or irregularity on a machined or scraped surface

burr file: A dull file for smoothing a burred surface

cam action: Movement of spindle in a direction parallel to axis of rotation caused by inaccuracies in manufacture; also called axial slip

canted: Slanted, as a scraper blade inclined at an angle to the work

carriage: The part of a lathe that slides on the bed ways and carries the cutting tool; sometimes referred to as the saddle.

chatter marks: A wavy surface formation which is caused by failure to alternate in successive scraping cycles the direction the scraper tool is thrust; also called wash-board finish

chore: A job repeatedly performed, such as cleaning the work surface at the end of each scraping cycle.

clamp: To fasten two or more pieces together by any convenient means

clamp, machinist's: A mechanical device having two parallel jaws: used for holding tools flat against bearing surfaces

coat: To spread, as a film of marking compound

compound: A marking medium used for indicating surface irregularities; a mixture of oil and pigment

compound bearing: A surface having two kinds of bearing quality, sometimes specified for special purposes

concave: Depressed or curved inward; dished

concentric: Having a common axis, as a spindle and spindle hole; or as the cylindrical portion and tapered shank of a test bar

contact point: the plunger or button of a DIAL INDICATOR

convex: Crowned or curved outward; humped.

criss-cross: In the form of an X

cross-rail: The part of a planer that permits transverse movement of the tool which it carries

crown: A convex contour; hump

cycle: In scraping work, a complete sequence of operations between successive applications of marking medium.

cylindrical: Roundness, used in speaking of test bars, spindles and spindle holes

dead center: A non-rotating support for revolving work, as the dead center of a lathe tailstock.

defect: A flaw in a surface

dent burr: A crater-like depression formed in a surface by the blow of a blunt instrument.

design: Model or type of machine construction

device: A mechanical apparatus, as a tool, jig etc.

dial test indicator: A precision instrument for measuring the dimensional variations of a surface, or the divergence from parallelism between two planes, or out of roundness of a cylinder.

diameter, horizontal: The distance through the axis, from side to side, measured horizontally.

diameter, vertical: The distance through the axis, from top to bottom, measured vertically

dig in: To gouge a surface by accidentally tipping the scraper blade sidewise

dovetail, female and male: A form of bearing which takes its name from a dove's tail which it resembles. The female type is characterized by a groove, the male type which is a projection inserts into the female part. When a gib piece is inserted between them a sliding fit is obtained and motion is then possible only in one plane.

down time: The idle period while a machine is out of commission

duplicate: To copy, as to produce an identical angle in a template, slide or way

eccentricity error: The disparity between the true center of a rotating shaft and its axis of rotation.

edge, cutting: The ground and honed end of the scraper blade.

elliptical: Oval, said of a run out of a spindle or test bar

end for end: To reverse the ends of a piece

end play: The lengthwise movement of a shaft in its bearings

error: The discrepancy between the indicated measurement and the required measurement; a shortcoming; a misalignment

essential: Necessary; indispensable

establish: To locate, as a check point from which measurements are made

face: A bearing surface, usually the most prominent surface of a machine or part

face plate: A metal disc attached to the spindle of a lathe and used for run out tests

fatigue: Physical strain induced by a cramped position, inadequate illumination or long continued application

feather edge: A thin sharp edge produced by scraping, honing or grinding

feeler: A thickness gage; a thin strip of metal used to check the space between two surfaces. Often made in a set containing several leaves of different caliper.

fillet: The curved juncture of two interior surfaces; a rounded inside corner

film: A thin coating, as of marking compound

fine edge: A highly sharpened cutting edge

finish: Surface smoothness measurable with a profilometer and expressed in units of R. M. S. (Root Mean Square)

finished surface: A smoothly scraped bearing with all minute ridges and tool marks removed

fit: To properly associate two bearing surfaces, as close fit, sliding fit, press fit etc.

fitting: The process of alternate spotting and scraping that has for its purpose the close joining of two surfaces

flake: To incise or cut, as to flake oil pockets into a surface

flat surface: One characterized by an absence of depressions or elevated areas; a plane

flaw: A defect in the structure, as a warp or blow hole in a casting, or as a scratch in the surface finish

flexible: Yielding; not rigid, as a feeler gage

flimsy: Lacking strength or stability

footstock: A grinding machine attachment having a dead center that supports the end of the work piece opposite the work head

frost: To produce a decorative design in the scrape-finished work surface

furrow: A deep scratch in a metal surface

gage: An instrument or tool for indicating or measuring, as a surface plate, a dial test indicator etc.

gage, surface: A device having a flat base and an adjustable upright beam for holding a DIAL INDICATOR

gearing: The apparatus for transmitting motion

generate: To produce; to make, as to generate three surface plates from rough castings by the application of the principle of the Symmetrical Distribution of Error.

gib: A relatively long, thin and narrow piece of metal inserted between two machine members to provide a bearing and adjustable to varying degrees of sliding pressure by means of bolts or screws.

gib slot: The opening between a stationary member and the sliding member in which the gib piece is inserted

goggles, safety: A spectacle frame mounting lenses of clear shatter resistant glass worn to protect against flying particles of metal loosened by grinding, hand sanding, and similar operations

grease: A semi-solid lubricant applied to the flat bearings of some machines

grind: To remove a thin skin of metal by means of a rapidly rotating abrasive wheel; to sharpen, as a blade

grinder: A category of precision tools that divides basically into machines that grind cylindrical surfaces, or grind flat surfaces; a machine for sharpening cutting tools

grit: Granular material such as sand loosened from a casting

groove, clearance: A straight channel of semi-circular form, about 1/4" in diameter, cut at the inside junction of two bearing surfaces. Its purpose is to improve spotting and scraping efficiency and allow full seating of mateing members.

groove, oil: A recess cut in a bearing surface to serve as a reservoir for lubricant

guard: A sheath or shield to protect the tool or worker from accidental contact

guided slide: The bearing surface of the sliding member that is fitted to the guiding way of the stationary member

guiding way: The bearing surface of the stationary member that regulates the direction of movement or alignment of the sliding member

hacksaw blade: A fine-toothed, narrow blade of tempered steel used for

cutting off; also adaptable to cutting grooves in metal surfaces

half-nut: A threaded piece of metal that is split lengthwise, and clamped around the lead screw, as the half nut of a lathe carriage

hardened: As applied to metal, an object so treated that it is harder than normal

headstock: The member of a lathe that revolves the work by means of a rotating spindle

heat treatment: Any process of improving the physical qualities of metal by application of heat

height: The distance upward that one surface is from a measuring point

helper: An assistant to the operator or mechanic in charge

hone: A fine grit bench stone; to sharpen a cutting blade

horizontal: In a position parallel to the horizon

horizontal plane: A plane that is parallel to the horizon

identical: Exactly the same; a duplicate

impair: To damage, as to impair the surface finish by inexpert handling of the scraper tool

impractical: Possible but not economical from the standpoint of expended time, effort or cost

indicate: To register; to give a reading

indicating jig: A device having a frame and four or more legs designed to hold a dial test indicator; a fixture used primarily for testing parallelism

in line: Being in the same center or the same plane

insert: To put in; to introduce; as to insert a test bar in a spindle hole

instrument: A mechanical device capable of providing precise measurements, as a dial test indicator

invert: To turn upside down; reverse top to bottom

jiggle: To shake, as to jiggle a machine member when making a Shake Test

keen: Sharp; fine-edged

knee: A machine member gibbed to the column of a milling machine to providing vertical adjustment; also guides the saddle-table assembly out and in horizontally

lap: To polish or finish with a lap.

lathe: A versatile type of machine tool used for turning metal in cylindrical form. With suitable attachments many other operations such as drilling, milling, taper turning etc. are possible.

level: Parallel to the horizon.

level, precision: A spirit level having two horizontal glass vials square to each other; used for erecting machinery and aligning surfaces during scraping-in process.

leveling surface: The place, or places, on the main casting or bed, whereon to lay a precision level while adjusting a machine to the horizontal plane.

line-up: To align, as gears or shafting.

live center: That part of the headstock which supports the revolving work piece.

longitudinal: Running lengthwise; differentiated from cross-wise.

lubricant: Any substance that has the property to reduce friction between working parts.

machine tool: A precision built machine designed for general use in a machine shop that cuts, drills, or shapes metal to close tolerances.

machinist: A mechanic skilled in the operation of machine tools.

maintain: To keep in good repair, as a machine.

maintenance man: A specialist in the upkeep of machinery.

major axis: The greater of two axes, as the ellipsis of a test bar run out.

mallet: A small hammer with a wood head used for fitting gib pieces into slots.

manipulate: To handle dexterously.

mar: To damage or disfigure a surface, as by a scratch.

Master Surface Plate: A plate of proven accuracy used exclusively as a standard of reference for testing other Surface Plates or Straight Edges.

match: To fit one surface to another with maximum contact i.e. area contact.

mateing member: The member that matches another, as a table sliding on a saddle, a knee on a column etc.

mean: The mid-point between extremes, as halfway between the major and

minor axes of rotation of a test bar.

mean position: The average eccentricity error.

method: A systematized procedure.

micrometer, vernier: A micrometer calibrated in tenths of thousandths of an inch.

milling machine: A machine tool wherein the work is shaped by means of a rotating multiple tooth cutter tool.

mount: Affix to or position upon, as a carriage mounted on a lathe bed.

obtuse angle: An angle greater than 90^{o}.

O. D.: Abbreviation for outside diameter.

off-hand scraping: A procedure performed without alternate spottings of the work surface, consequently faster but less accurate, never feasible except where a large excess thickness of metal provides a reasonable margin of safety.

oilstone: A bench stone for sharpening tools, oil being the lubricant.

on center: A condition wherein the cutting edge of the tool is at the same level as the axis of the centers. If higher or lower it is above or below center respectively.

ooze: To spread or run, as compound under pressure.

operator: The mechanic performing the scraping work or conducting alignment tests.

out of round: A shop term signifying that a shaft is not truly circular.

over arm: On a milling machine, the horizontally adjustable brace above the spindle which supports the arbor.

overhaul: To recondition, as to repair a machine.

parallax: The apparent displacement of the bubble in a vial of a precision level when viewed from two different points.

parallel: Equally distant in all parts, as parallel lines or parallel planes. In alignment work, tests are made for this quality in both horizontal and vertical planes, measurements being made longitudinally or transversely as convenient.

parallels: Hardened and ground or hand scraped steel bars used to support work. Thus a work piece placed on two identical parallels is parallel to the base supporting the tools.

particle: A small bit of matter, a piece of grit.

pattern: A copy; model.

peen: The rounded end of a hammer opposite to the face.

periphery: The circumference of a circular object or part, particularly one that rotates.

pitch: The distance from a point on a screw thread to a corresponding position on an adjacent thread measured parallel to axis of a shaft.

pivot joint: The highest part of a convex surface on which a spotting tool will teeter if balanced; a fulcrum.

plane: A surface without elevations or depressions.

planer: A machine tool capable of machining flat surfaces of large size. The work is fastened to a moving table and is passed under stationary cutting tools.

practice: A procedure; a proved method; a systematized routine.

precision: High accuracy that conforms to established standards.

prismatic way: An inverted V-way, as on some forms of lathe bed.

protractor: A tool usually equipped with a vernier scale, for measuring angles or laying out work.

push fit: A condition wherein a male part can be pushed into a female part by hand pressure.

ram: A retractable cylinder of a lathe footstock into which the dead center is inserted.

reading: A measurement, as a position on a calibrated dial face indicated by a pointer hand.

recondition: renovate, to restore to a good condition.

rectify: To set right; to correct; to make accurate.

red lead: A reddish-orange oxide of lead which ground to a fine powder and mixed with oil makes an effective marking compound.

register: To record, to indicate a reading on a test instrument.

repair: Put in good operating order; replace worn parts.

resultant: two or more requirements to be accomplished in a single operation.

revolve: To turn, as a shaft.

rigid: Unyielding, not pliant.

Rockwell Hardness Test: A system of testing the hardness of metal, by measuring the depression caused by a test point under controlled conditions.

Root Mean Square: Abbreviated to R. M. S.; a formula for measuring surface finish. The high and low spots are measured in micro inches at equally spaced intervals from a Datum Line. These measurements are squared, then averaged, and the square root taken. The resultant is a number which is used as a criterion of surface finish.

rotate: To turn or revolve as a spindle about its axis.

run out: The amount a round object varies from a true circle in turning.

saddle: That part of a milling machine that provides out and in movement; rarely the carriage of a lathe.

safe edge: Said of a file having one smooth edge. A file with the teeth ground off on one edge.

sag: A deflection from straightness; a condition particularly noticeable in solid test bars when held at but one end.

salvage: To save used parts for further use, as when reconditioning.

score: To make a deep scratch.

scrape: To effect the removal of metal from a surface by means of a scraper blade.

scrape-finished: The condition of a bearing surface after a final smoothing with a scraper blade.

season: To age a metal casting; to normalize.

seat: To position, as one machine member on another.

sensitive: Being easily actuated, as a dial indicator; responsive to slight changes in position, as a precision level; delicate.

shim: To place a thin flat piece of metal or paper strip between surfaces to effect an alignment; to drive tapered wedges of metal or wood under a casting to level it.

shore: To brace or block a casting to prevent movement.

side play: The amount of longitudinal movement necessary for running parts to adjust themselves.

slides: The bearing surfaces of the sliding member.

sliding pressure: The condition of tightness existing between two members after the adjustment of the gib.

slot, adjusting: The milled hole at the end of a tapered gib receiving the adjusting screw.

slot, gib: See "gib slot".

solder: An eutectic alloy used for filling blow holes or vents in a bearing surface.

spindle, dead: The retractable, non-rotatable ram of the tailstock of a lathe or the footstock of a grinder.

spindle, live: The driving spindle of a machine tool.

spirit level: Also precision level; an instrument for judging the deviation from the horizon by means of an air bubble sealed in a vial of alcohol.

spotting: A process involving transfer of marking compound from or to a surface for the purpose of indicating surface irregularities on a piece of work.

spotting tool: A gage or template utilized to transfer marking compound.

square: To be at an angle of 90°; a tool designed to indicate conformity with this condition, as a Try Square.

stabilized: Said of a surface condition rendering relatively consistent markings on successive spotting cycles; also a condition in which strains and stresses in a casting have been relieved.

standard: Established, as a proved method or practice.

steel block: A flat piece of steel used to knock down or dull the sharp points of burrs.

straight edge: A tool much longer than it is wide having one true flat surface. Used for spotting.

surface plate: A precision tool notable for flatness having a surface quality of 30 - 35 bearing spots per square inch. It is used variously as a Datum Plane and for transferring marking compound.

synchronize: To schedule operations so as to obtain several results simultaneously; said of the procedure involved in attaining OBJECTIVES.

table: The horizontal working surface of a machine tool having T-slots which are designed to hold down the work piece or auxiliary fixtures.

take-up: In a gib piece the adjustment available to overcome looseness.

taper: A cone shape; coming to a point at one end.

target: The straight portion of a test bar used as a contact surface for measuring.

tempering: The treatment accorded steel to relieve strains and provide the proper hardness without brittleness.

tension: The strain or pressure imposed on machine parts by gib adjustment.

test block: A hardened steel block ground parallel on two sides, utilized for tests requiring an area contact on a surface.

tilt: To cant; to incline from a level position.

tolerance: The permissible error in a specification, either bi-lateral or unilateral.

top finished surface: A non-bearing surface machined parallel to adjacent bearing surfaces. Frequently used as a leveling surface.

transverse: The cross-wise direction, as opposed to longitudinal.

true: To make accurate; to align correctly.

true running: Said of a test bar whose axis is in line with the axis of revolution; a condition proved by a test between centers.

T-slot: In a table, slots having the form of an inverted "T" milled lengthwise, used for clamping fixtures or the work piece.

T-square: See Square.

uniform: To be without variation; constant, as marking compound smoothly and evenly distributed.

unwieldy: Not easily handled, said of a casting.

vary: To modify or change in some fashion.

vertical: At 90° to the plane of the horizon.

warp: To bend or twist out of alignment; a wind.

ways: The bearing surfaces of the stationary member on which the slides of the sliding member move.

wear: Abrasion or deterioration of a surface by sliding friction.

weight: The load carried by a member.

wind: A twisting or warping away from flatness or straightness of parallel bearings.

wiper: A felt or metal strip attached to the ends of a sliding member to brush away dirt or chips from the ways of the stationary member.

work: The surface being treated; also called the work piece.

zero-zero: A term meaning that there is no deviation in the dial indicator readings taken at two points on a test surface, as measured from a Datum Point;

zeroed: A shop term signifying the adjustment of a dial indicator to permit the pointer to swing either side of "0" as pressure on the contact button increases or decreases. This is arranged by imposing some pressure on the plunger or contact button then twirling the face of the instrument until the "0" corresponds with the pointer.

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